SimSEE

SimSEE User Manuals

VOLUME 3

Actors.

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Index

1. Introduction

This is VOLUME 3 of the SimSEE User Manuals and is dedicated to serving as a Reference Manual for the different Actors models. If you are not familiar with SimSEE terminology it is recommended that you first read the Introduction of VOLUME 1.

The Actors classify the following Groups that correspond to the Tabs in the Editor:

- **Network.** With the Actors of this group it is possible to model the electricity grid. The available Actors are Nodes and the Arches. The Node represents a connection bar where Actors can deliver or withdraw energy. With the Arcs it is possible to model the connection between the Nodes. The Arc allows energy to flow from one node to another.
- **Loads.** It is formed by the set of Actors that represent the energy consumption of the system. All demand must be associated with a system Node.
- **Wind Farms.** With this type of Actors it is possible to edit the wind power plants (wind farms) of the electrical system. All wind power plants must be associated with a Node of the system.
- **Solar.** This group corresponds to generation plants based on solar energy. Both thermo-solar and photovoltaic.
- **Fuel-fired.** This group is formed by the different types of thermal power plants that operate based on fossil fuels, biomass and solar thermal. All thermal power plants must be associated with a system Node.
- **Hydroelectrics.** This group is made up of the different types of hydroelectric plants.
- **International and Others.** It contains the Actors that describe the capacities and modalities of exchange with neighboring countries. Also available within this tab are Actors rarely used as the Actor Bank of Batteries.
- **Responsive Demand.** This type of actor allows modeling the percentage of demand that can be managed through economic signals.
- **Fuel Network.** This tab includes a group of actors that allow the definition of a fuel network, generating plants that feed on the fuel network and generate electricity, fuel suppliers and regasification plants for Liquefied Natural Gas.
- **Without editor.** Here are the Actors who do not yet have an editor in SimSEE, but it is possible to edit them as text and work with them.

The following sections describe the Actors belonging to each group.

To facilitate the description and fulfill the purpose of being a Reference Manual, for each Actor we describe:

- "Static Parameters" showing the editing form of the Actor in the Editor.

- "Dynamic parameters" showing the dynamic parameters record of the Actor in the Editor.

- “Reference in Pascal sources” indicating the Pascal Unit (this is the Pascal source file) in which the Actor's class is defined and showing the Actor's class tree.

- "Published Variables". Each Actor publishes a set of variables that can then be monitored during Optimization / Simulation or can be post-processed with the SimRes3 chronic results processor. To publish the variables, the Actors use the “PubliVars” method and a table like the one shown in Table 1 is included in the description of each actor. The first column shows the Name with which the variable is published, the second column shows the units in which it is published. The column “Time Bands” indicates whether the variable corresponds to a value per time band (Yes) or if it is a value per step in which case it will say (No). The column “SR3” indicates whether the variable besides being published (which allows it to be used on the monitors) is exported by default in the output file that is usable by SimRes3. Finally, the column "Description" indicates the meaning of the exported variable. The variables "per time band" (_Pi = Si), as shown in the example table, are published in their values per time band and to identify the time bands "_Pi" is added at the end of the name with "i" the time band number . For example, if the variable "cmg" refers to the marginal cost of a node in a 3-post room, 3 variables with names "cmg_P1", "cmg_P2" and "cmg_P3" will be published.

Tabla 1: Example of an actor's publication box of variables.

Name	***Units***	***_Pi***	***SR3***	***Description.***
cmg	USD/MWh	Si	Si	Marginal Cost of the Node in time band "i". It is the cost that would be incurred to supply an additional MWh of demand at the node.

2. Network Group.

This group has the Node and Arc type Actors; which serve to model the power grid in SimSEE.

Nodes are the connection bars to which generators and demands are added. They represent the large areas of the system agglutinating a set of "bars" of real connection. The Arcs interconnect the nodes and allow modeling a limit of energy transfer capacity, performance and a toll. In this way, the large areas of the system and the limits of energy exchange capacity between them can be modeled in a rustic way. SimSEE has a Load Flow program (FLUCAR) that can interact with the representation of the network to check by executing the load flow over the detailed electricity network and adjust the capacity and performance limits so that the energy dispatch is representative of what is possible to do in the electrical office.

2.1. General Characteristics of the Actors.

The description of the general functionalities of the Actors is presented below.

The Actors are configured through parameters that can be Static or Dynamic.

The Static Parameters are the ones that do not change during the optimization and simulation process.

Dynamic parameters are the ones that can change at each time step during the optimization and simulation process.

2.1.a)Payments (not considered for energy dispatch)

All generators have the possibility of specifying Payments for Energy and Payments for Power (or capacity).

The Power Payment is expressed in USD/MWh and is a payment that an Actor can receive, when available, for the power made available. Payment by power is not considered for the purposes of the resolution of the optimal dispatch. It is useful to represent the fixed costs associated with the generator. It is generally calculated as the payment that remunerates the investment and the fixed costs of operation and maintenance.

Payment for energy, is expressed in USD / MWh and is an additional payment to the variable cost that an Actor can receive for the energy delivered to the system. Like the payment for power this parameter does not intervene in the optimization of the economic dispatch. It is a cost that is added to the cost of supplying the demand.

Both payments can be used to represent the contractual conditions of the Actor in the Electricity Market.

2.1.b) Payment index.

In the Payment Index selector, you can specify a terminal of a source, whose purpose will be to multiply the payments of the panel “Payments (not considered in the office)”. If a source is not specified, the multiplier is 1.

2.1.c) Price index per fuel.

The Fuel Price Index selector allows you to specify a terminal of a source whose purpose will be to multiply the variable cost. If a source is not specified, the multiplier is 1. The multiplier is in per unit of the price.

2.1.d) Investment gradient.

It is understood by Investment Gradient (GI), at each time step, to the difference between the Marginal Replacement Benefit (BMS) of the energy delivered by the actor and the Payments for Energy (PE) and Power Payment (PP) that the actor receives at the same time step.

$$GI = BMS - PP - PE$$ ec.(1) Investment Gradient..

The BMG is calculated as shown in ec. . If the Actor generates an energy E, the cost $E\,cv$ will be incurred but the cost $E\,cmg$ in the generating units whose energy is reduced will be avoided.

$$BMG = E(cmg - cv)$$ ec.(2) Marginal substitution benefit.

Si $GI > 0$ el generador en ese paso de tiempo “crea valor” dado que el beneficio creado por reducir el costo e generación (BMS) es superior a los pagos requeridos por el generador. A la inversa, si $GI < 0$, el genedor “destruye valor” es ese paso de tiempo. Conversely, if $GI > 0$, the generator "destroys value" is that time step. As the investments are remunerated in terms of 10 to 20 years, it can happen that a generator does not generate value (or destroy value) in certain periods (for example in spring) but that the value created in other periods compensates for the loss. For this reason, the integrated value is usually looked at more than the GI per time step (thus filtering seasonality and simulated randomness). In the stages of the analysis horizon where the expected value of the GI integral is horizontal, the generator is in equilibrium, in those in which the expected value of the GI integral shows positive slope, it is indicated that it would be profitable to increase the power of the generator and in which it is negative it would be profitable to install less power from that generator.

In the “Simulator” tab of the editor there is a box that allows you to specify “Calculate Investment Gradient in p.u.”. If unchecked, the GI is calculated as specified in ec.1. If the box is checked, the GI is calculated in per unit of the power payment as shown in ec3.

$$gi = \frac{BMS - PP - PE}{PP}$$ ec.(3) Investment gradient in per unit of fixed costs.

2.1.e) CO2 emissions.

The “CO2 emissions” table is also specific to the generators and allows to indicate the tons of CO2 per MWh generated, if the generator is of the “Low Cost Must Run” type and if it participates in a program of the Clean Development Mechanism type.

The Calculate CO2 Emissions box enables or not the calculation. If enabled, it is generated by simulating a file with the expected emission of each generator, with different indicators.

2.1.f) Available Units.

In Available Units you must specify how many units are available in a certain period of time. Selecting the button opens a panel that allows, by adding new tabs, to define the number of units installed and maintained by date. When a new record is added, the validity date from which the detailed information in the fields of units installed and in maintenance is valid must be defined. Within each tab you can define if the unit has high uncertainty, which means that the unit will be available at some time from the date of the record. The uncertain discharge date is obtained by means of a simulation time draw.

Start of uncertain chronicle. This option of the unit cards allows to specify the treatment of the availability of the generating units at the beginning of each chronicle. The use of this option may be different if the case study corresponds to the short-term analysis starting from a well-known current situation or if it is a study on a future horizon where the initial situation (this is at the beginning of the horizon) is uncertain

If the “Uncertain Chronic Start” box is checked, at the beginning of each simulation chronicle, instead of assuming that the units are actually available, raffles are made and will be available according to the Availability Factor specified for that generator.

2.1.g) Forced units.

The actors subject to the power dispatch, support the possibility of being defined, forced dispatches. It is possible to impose a dispatched power value, impose a minimum dispatch, a maximum dispatch or a range of dispatch power. These parameters are handled by dynamic parameter tabs and are edited as described in chapter 3 of the editor's manual.

2.1.h) Rotating Reserve.

The Rotating Reserve Factor is a factor in p.u that multiplies the maximum power generated by the Actor for each time post to determine the Actor's contribution to the Rotating Reserve.

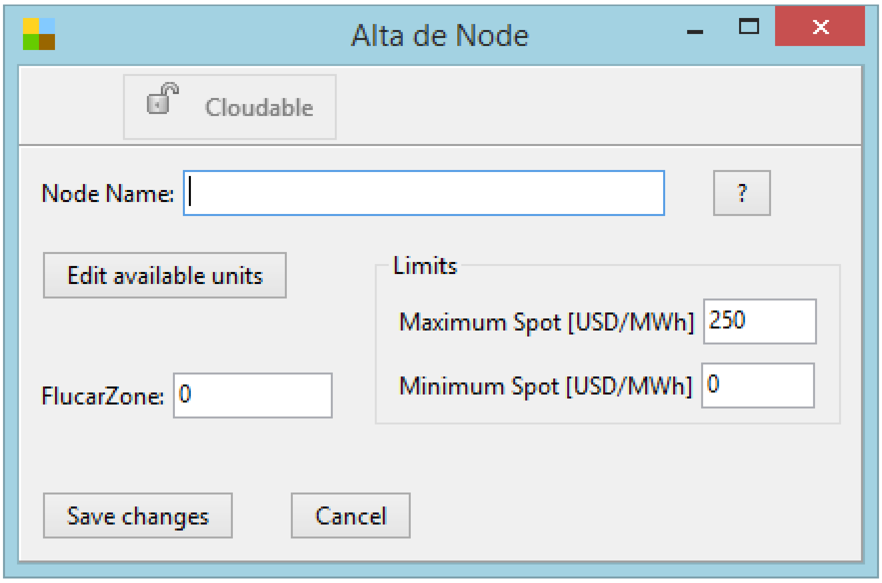
2.2. Node.

The Node is an Actor belonging to the Electric Network. The Actor represents a connection point for injecting or extracting power.

The function of the Node is equivalent to a connection bar where different Actors can deliver energy or consume energy.

2.2.a) Operation description.

The registration form of the Node is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

At each Node it must be instantly fulfilled that the Node's power balance is zero on each post of each time step.

2.2.b) *Static parameters.*

The static parameters are the Node Name, the “FlucarZone” that allows the Node to be associated with a “Zone” of the Electric Network for the iterations with the FLUCAR power flow program.

In the "Limits" panel you can define the maximum and minimum value that the Spot price of the Node can take.

2.2.c) *Dynamic parameters.*

The Actor has no dynamic parameters, since its parameters do not vary during simulation.

2.2.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
cmg	USD/MWh	Yes	Yes	Marginal Cost of the Node in the post i. It is the cost that would be incurred to supply an additional MWh of demand at the node.
Cmg hourly	USD/MWh	Yes	Yes	Hourly Marginal cost.
Spot	USD/MWh	No	Yes	Node Spot Price.

2.2.e) State variables, Control and Restrictions.

The Actor does not introduce State Variables, nor control the optimization problem.

The Actor introduces an equality constraint to be respected in each time post k . It must be instantly fulfilled that the balance of input and output power is zero, as shown in ec.1.

$$\sum_{i=1}^{i=N} P_i - \sum_{j=1}^{j=M} D_j = 0$$

ec.1 Balance in the Node in the time post. k .

Where:

P_i : Input power i .

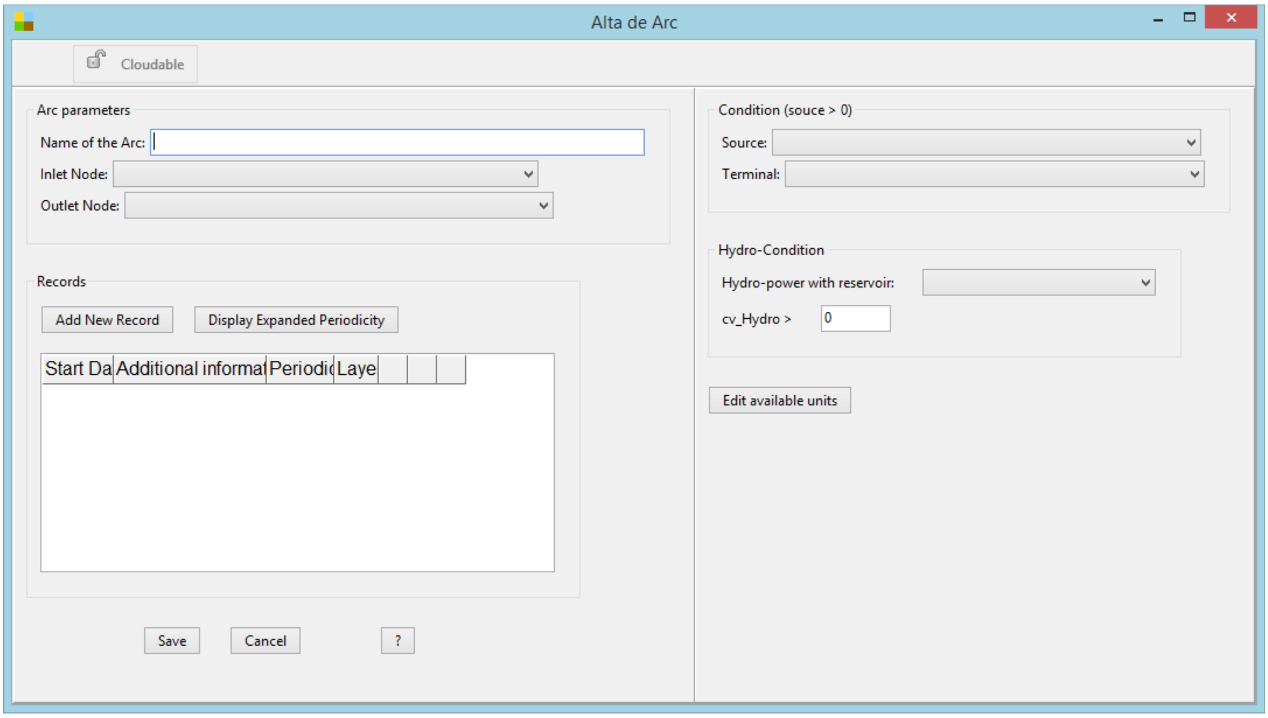
D_j : Output power j .

2.3. *Arc.*

The Arc is an Actor belonging to the Electric Network. The Actor's function is to make the connections between two Nodes of the system and thus allow the flow of energy between them. The electric power transport network is modeled from Nodes and Arcs, defining in the Arcs the possible capacity and availability restrictions.

2.3.a) Operation description.

The registration form of an Arc is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

2.3.b) *Static parameters.*

The static parameters are the Name of the Arc, the Input Node and the Output Node.

Since the Arcs are unidirectional, they have an Inlet Node and an Outlet Node. Energy can only flow through the Arc, from its Inlet Node to its Outlet Node. If between two Nodes it is necessary to represent a bidirectional transport corridor, two Arcs must be used, one in each direction.

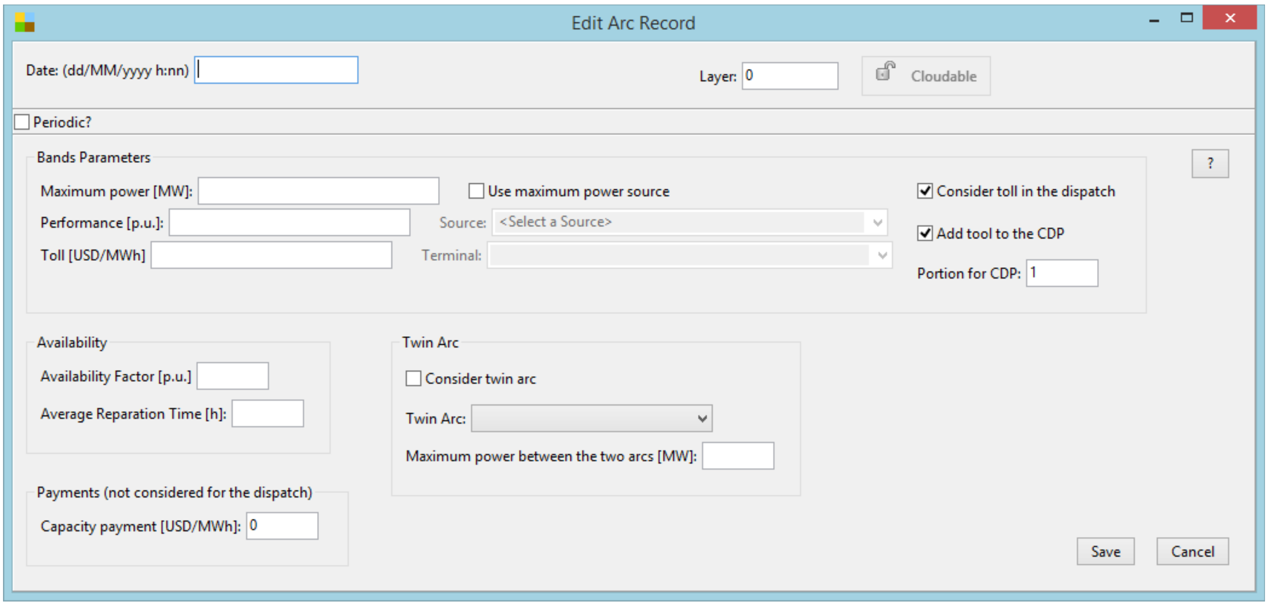
In the "Condition Source> 0" panel, it is possible to define whether it is desired that the Arc becomes unavailable if the value defined by a Source (specified in Source and Terminal) is less than zero.

In the “Hydro condition” panel, it is possible to define whether the Arc is to become unavailable if the water value of the hydroelectric power station selected in “Hydro with Reservoir” is greater than the value specified in “cv_Hidro”.

2.3.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

Maximum power: It is the maximum power in MW that the Actor can transfer between the input and output Nodes. If the “Use maximum power source” box is selected, a Source and Terminal can be specified so that the Actor receives the maximum power value.

Performance: The losses of the transport system in p.u. It is represented as a factor that multiplied by the input power of the Arc determines the output power. For example, if the yield is 0.9 this means that when the incoming power to the arc is 10 MW, the outgoing power will be 9 MW.

Toll: It is the toll in USD/MWh for the use of the Electric Network.

It should also indicate if you want this toll to be considered for the dispatch and if you want it to add to the Direct Cost of the Step (DCS). In the case where you want to add, you must specify with what factor. By default the boxes “Consider toll in the dispatch” and “Add toll to the DCS” are active, and the Factor for DCS is set to 1.

The "Availability" panel defines:

- Availability Factor: It is the availability factor in p.u. and determines what percentage of the time the Actor is in service and operating outside the scheduled maintenance windows.
- Average Reparation Time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.

In the “Twin Arc” panel a constraint can be imposed between two Arcs, so that the sum of the transferred power of each Arc is bounded to a specified value. If the “Consider Twin Arc” box is activated, the other Arc to be considered in the restriction and the maximum power that both Arcs can transfer must be defined.

2.3.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
P	MW	Yes	Yes	Power injected into the Node.
Cost	USD	Yes	Yes	Cost associated with the toll for transporting P on post i
CongestionCost	USD/MWh	Yes	Yes	Value per post of the Lagrange multiplier of the Pmax restriction.
NAvailableLines	u	No	Yes	Number of available lines in the time step.

2.3.e) State variables, Control and Restrictions.

The Actor does not introduce State Variables to the system.

The Actor adds 1 Control Variable per time post i :

- P_i : Power output.

The Actor introduces an equality constraint and two inequality constraint in each time post. It must be fulfilled instantly that the balance of power input and output zero, and that the powers are limited to Pmax, as shown in Eq. 1.

$$P_E.\eta - P_S = 0$$
$$P_E \leqslant PMax$$
$$P_S \leqslant PMax$$

ec.1 Power balance in the Arc per time post k .

Where:

P_E : Input power to the Arc.

P_S : Output power to the Arc.

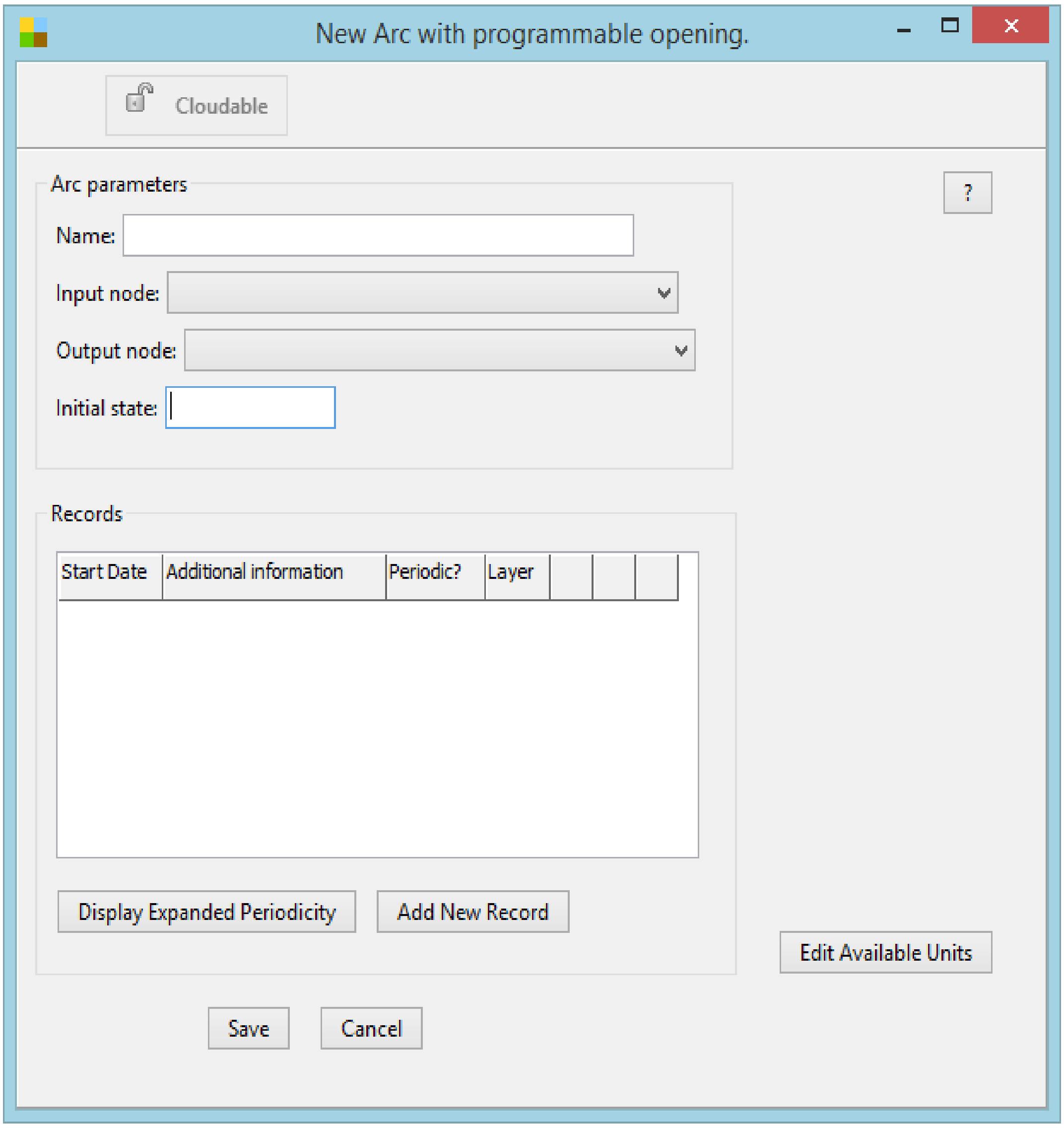
η : The losses of the transport system.

2.4. Arc with Programmable Opening.

The Arc with Programmable Opening is an Actor belonging to the Electric Network. The Actor's function is to make the connections between two Nodes of the system and thus allow the flow of energy between them. The Arc with Programmable Opening is able to interrupt the flow of energy (open the Arc) with some pre-established warning.

2.4.a) Operation description.

The registration form of an Arc with Programmable Opening is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

When the Arc goes out of service, the generators that are connected do not have the possibility of transporting energy through it.

To manage the warning order, it is necessary to add a state variable to the problem, since once the decision is made it is indefeasible and the disconnection is made when the warning time ends. Once the disconnection period is over, there is a minimum operating time without the possibility of programming a new disconnection.

2.4.b) *Static parameters.*

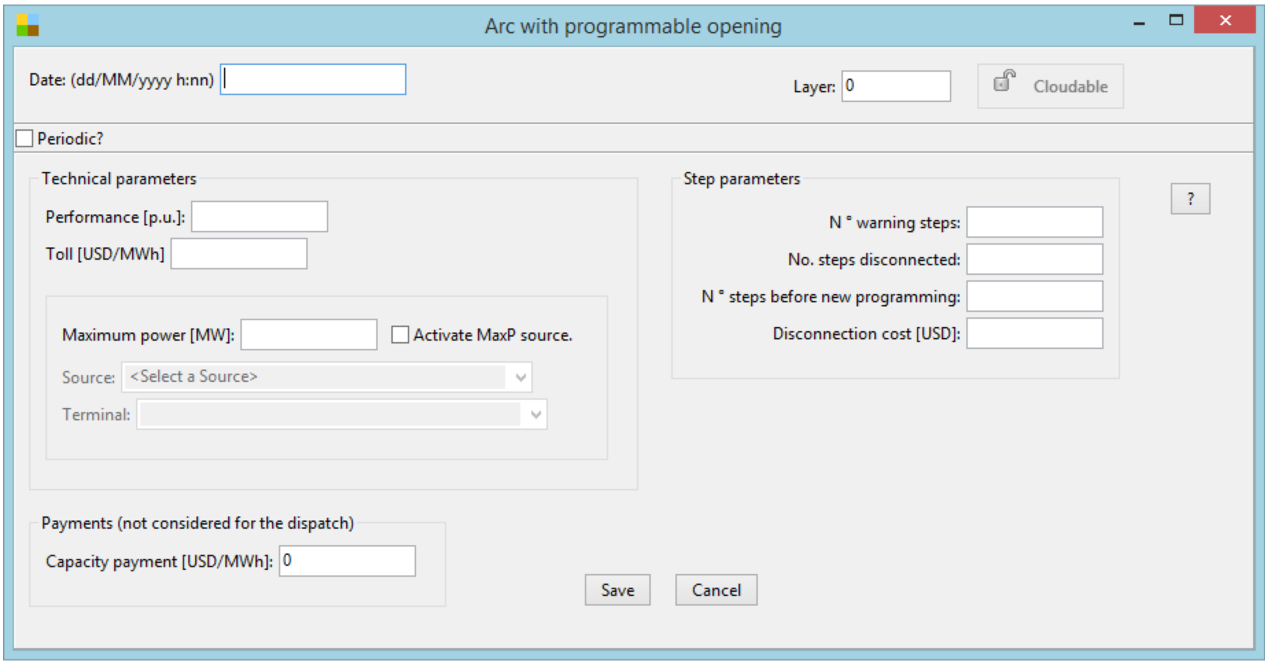
The static parameters are the Name, the Input Node and the Output Node.

In "Initial State" it is necessary to indicate the initial state of the Arc. The initial state is the value at the beginning of each simulation chronicle of the state variable X_Desc. The value 0 (Zero) means that the Arc is connected and can be programmed.

2.4.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- Performance: The losses of the transport system in p.u. It is represented as a factor that multiplied by the input power of the Arc determines the output power. For example, if the yield is 0.9 this means that when the incoming power to the arc is 10 MW, the outgoing power will be 9 MW.
- Toll: It is the toll in USD/MWh for the use of the Electric Network.

It should also indicate if you want this toll to be considered for the dispatch and if you want it to add to the Direct Cost of the Step (DCS). In the case where you want to add, you must specify with what factor. By default the boxes “Consider toll in the dispatch” and “Add toll to the DCS” are active, and the Factor for DCS is set to 1.

- Maximum power: It is the maximum power in MW that the Actor can transfer between the input and output Nodes. If the “Use maximum power source” box is selected, a Source and Connection terminal can be specified so that the Actor receives the maximum power value.

These values must be specified as a vector of real numbers separated by ";" (semicolon). If only one value is entered, it will be applied to all posts.

In the "Step parameters" panel you define:

- Nº warning steps: Indicates the number of time steps that are necessary to pre-notice before the arc is disconnected.

- Nº of steps disconnected: Indicates the minimum number of steps to keep the arc disconnected once the disconnection occurs.

- Nº of steps before new programming: Indicates the number of steps that must be connected again before it is possible to program a new disconnection. This has to be greater than or equal to zero.

- Disconnection cost: Amount to be paid in dollars (USD) for each disconnection order.

In order to have the possibility of a disconnection in advance, a state variable is required that indicates whether the disconnection decision was already programmed or not and the time that has elapsed since it was programmed.

The state variable X_Desc is defined as an integer state variable.
If X_Desc = 0, the arc is connected and with the possibility of making the decision to schedule a disconnection (pre-warning order). Being in the state

X_Desc = 0, the decision can be made to schedule the disconnection or continue in the same state.

If the decision is made to disconnect (pre-warning order), the state at the end of the time step (Xs_Desc) will be: Xs_Desc = N ° Pre-warning steps, and from there, a countdown due to the pre-order is initiated.
While X_Desc> 1, the Arc remains closed allowing the passage of energy and value at the end of each step Xs_Desc = X_Desc - 1.

When the state X_Desc = 1 is reached, the Arc opens, thus preventing the transit of energy and the value of the state variable at the end of the step will be: Xs_Desc = - (N° Steps Disconnection + N ° Steps before new programming). In other words, the state becomes negative with the sum of steps in which it must remain disconnected plus the steps to wait after the connection for a new programming. As of this switching, a new countdown begins in which the Arc remains open for N° Steps Disconnection and then connects, but new schedules are not accepted until the counter reaches zero. While X_Desc <-N° Steps before new programming, the arc remains open and Xs_Desc = X_Dec +1 in each step.

When the value X_Desc = - N° Steps before new programming is reached, the Arc is connected, but new schedules are not accepted and the state variable continues increasing with each time step with Xs_Desc = X_Dec +1 until reaching the Zero value that it is the “idle” state of the Arc in which it is connected and it is possible to program outputs.

2.4.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
P	MW	Yes	Yes	Power injected into the Node.
CF	USD	Yes	Yes	Future Cost of the Actor
X_Desc		Yes	Yes	State Variable of disconnection.
NAvailableLines	u	No	Yes	Number of available lines in the time step.

2.4.e) State variables, Control and Restrictions.

The Actor adds 1 State Variable to the system:

- X_{Desc} : Integer variable that indicates whether the disconnection decision was already programmed or not and the time that has elapsed since it was programmed.

The Actor adds 1 Control Variable per time post i :

- P_i : Power output.

The Actor introduces an equality constraint and two inequality constraint in each time post. It must be fulfilled instantly that the balance of power input and output zero, and that the powers are limited to Pmax, as shown in Eq. 1.

$$P_E . \eta - P_S = 0$$
$$P_E \leqslant PMax$$
$$P_S \leqslant PMax$$

ec.1 Power balance in the Arc per time post k .

Where:

P_E : Input power to the Arc.

P_S : Output power to the Arc.

η : The losses of the transport system.

3. Demands Group

It is the group of Actors that belong to the “Demand” tab of the Editor. They are the Actors used to model the energy consumption of the electrical system (demand for electrical energy). All demand must be assigned to a NODE of the system (it consumes energy from the node). It is possible to create the following types of demands: "3 Time Curves", "Detailed Demand" and "Demand generated from a base year and annual energy vector".

3.1.a) Static parameters common to all demands.

Fig.1 shows an extract of the static parameters edition form that is common to the three types of demand

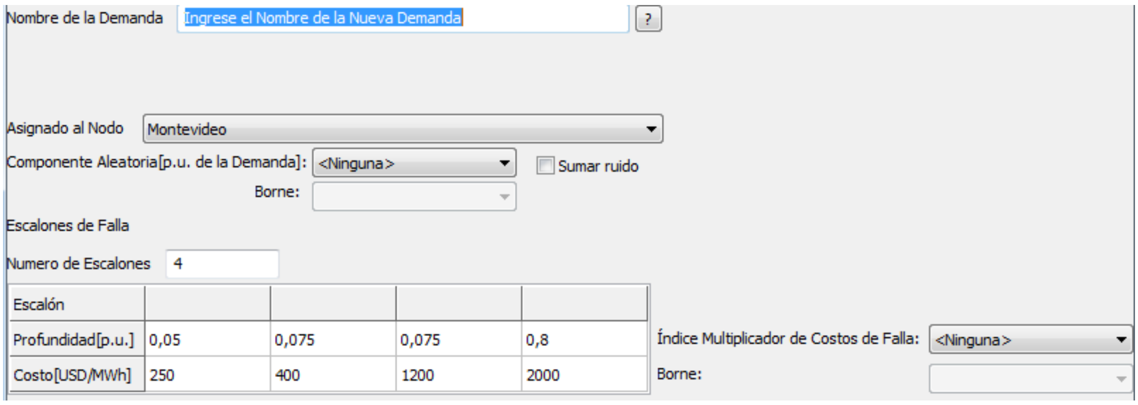


Fig. 1: Common parameters to all demands.

In the **"Demand Name"** field, a name must be indicated to the Demand. The **“Assigned to the node”** combo allows you to select between the nodes of the system in which the demand is connected.

In the selectors **“Random Component (p.u. of Demand)”** and **“Terminal”**, you can assign a random source that represents the variations (noise) of the demand. If the **“Add noise”** box is unchecked (as in the figure), then the noise is considered in per unit of demand. If the source value is "r", the demand value (without noise) will be multiplied by the factor (1 + r) at the time in question. If the **“Add noise”** box is checked, then the noise is considered additive and represents the MW to add to the value of the demand without noise. If you do not want to introduce uncertainty in the demand, you must indicate in the box of the **“Random Component”** the value “None”.

In addition to being able to model uncertainty in demand, the Source can also be used to simulate different demand scenarios including a Source with different growth.

Continuing with the description of the parameters in Fig. 1 the area of the form destined to the description of the “Fault Steps” begins.

The **“Number of steps”** box indicates the different number of fault steps to consider. Once the number of steps has been indicated (4 in the example) the table with the depth and cost values is updated to allow to enter as many corresponding values. The steps are considered ordered from left to right. The **“Depth [pu]”** is the depth of the step in per unit of the demand, and the **“Cost [USD / MWh]”** is the cost to consider for the economy of the country of a failure in the supply of the demand that reaches that depth. In the example, the depths are 0.05; 0.075; 0.075 and 0.8 and the respective costs are 250; 400; 1200 and 2000 USD/MWh respectively. In the example, in case of a demand supply deficit, for the first 5% a cost of 250 USD / MWh will be computed, if the deficit exceeds 5%, over the first 7.5% exceeds 5% a cost of 400 USD / MWh will be computed. If the deficit exceeds the sum 5% + 7.5% over the surplus, the first 7.5% is computed at a cost of USD 1200 / MW and if the deficit exceeds 5% + 7.5% + 7.5% for the surplus, in addition to the calculations from the first three steps a cost of 2000 USD / MWh will be computed for the surplus. To be consistent in the use of the failure steps, the depths must add 1 (one) and the failure costs must be increasing from left to right.

The **"Fault cost multiplier"** selector (and the corresponding Terminal) allows you to select a Source to index the failure costs. This is useful because in long-term Rooms in which fuels have indexation, it is reasonable to index the failure costs so that the system resources do not end up being more expensive than the failure costs. If there are cheaper resources in the system than the failure, the optimizer will dispatch the failure before those resources. This may be a desired behavior for a demand that is able to "get out" of the system when costs are high; but it is hardly the case of the main demand of the country, so care must be taken with the relationship between the costs of failure and resources so that the modeling fits the actual operation of the system.

3.1.b)Reference in common sources to all demands.

All demands are descendant models of the class TDemand defined in the Source and with the inheritance chain that is summarized below:
Source: *..src\fc\actores\udemandas.pas*
Heritage: TActor>TActorNodal>TActorUniNodal >TDemanda

3.1.c) Published variables common to all demands.

The Tdemand class publishes the variables shown below and are therefore published by all types of demands.

Name	***Units***	***_Pi***	***SR3***	***Description.***

P	MW	Yes	Yes	Power injected into the Node in post "i". (as it is a demand it will be normally negative).
PD	MW	Yes	Yes	Power of the Demand. (It is minus the previous one when there is no FAILURE)
PFj	MW	Yes	Yes	Failure Power dispatched in the "j" failure step in the "i" post.
Costoj	USD	Yes	Yes	Failure cost of step "j" on post "i".

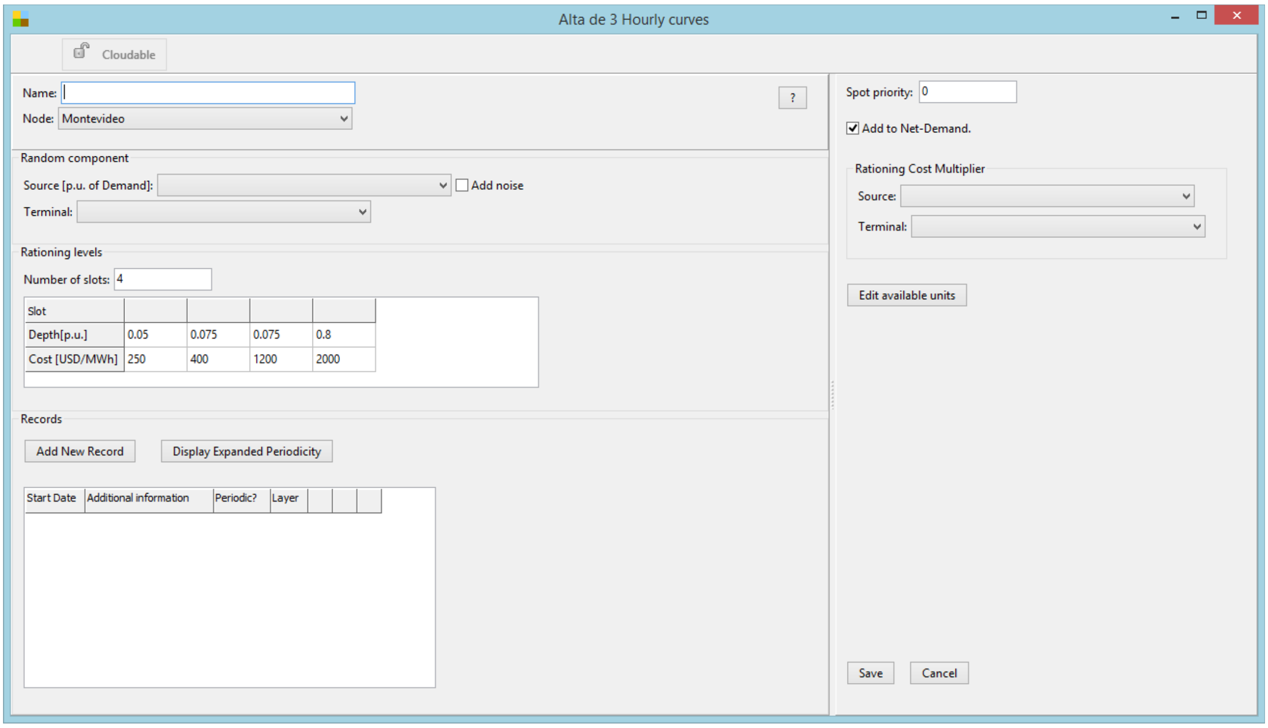
(TDemanda01, TDemandaDetallada, TDemandaAnioBaseEIndices)

3.2. *3 Hourly Curves Demand.*

The 3 Hourly Curves Demand is an Actor belonging to the Demands group. The Actor represents the electrical energy consumption of the electrical system (electric power demand) by defining the hourly consumption curve for three types of days: Business Days, Half-Holidays and Holidays.

3.2.a) Operation description.

The registration form of the 3 Hourly Curves Demand is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

3.2.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network with which you want to associate the Actor.

In the “Random Component” panel, a Source and Termial selectors are available to assign a random source that represents the variations in demand around a preset value. The random source must generate the noise in p.u. of the demand. The value used in each time step will be the deterministic value multiplied by

(1+ r) where r is the value read from the source. In the case where you do not want to use random sources, you must specify the option “None” in the box and the multiplier in this case is 1.
In addition to being able to model uncertainty in demand, the source can also be used to simulate different demand scenarios including a source with different growth.

3.2.b.i Rationing levels:

The “Rationing Levels” panel indicates the number of Rationing Levels to consider. Once the number of levels has been indicated (4 in the example), the table with the Rationing Depth and Rationing Cost values is updated to allow entering the corresponding values. The levels are considered ordered from left to right.
The Depth [p.u.] is the depth of the level in the demand measurement unit and the Cost [USD / MWh] is the cost for the country economy of a failure in the supply of the demand that reaches that depth. In the example, the Rationing Depth are 0.05; 0.075; 0.075 and 0.8 and the Rationing Costs are 250; 400; 1200 and 2000 USD / MWh respectively.

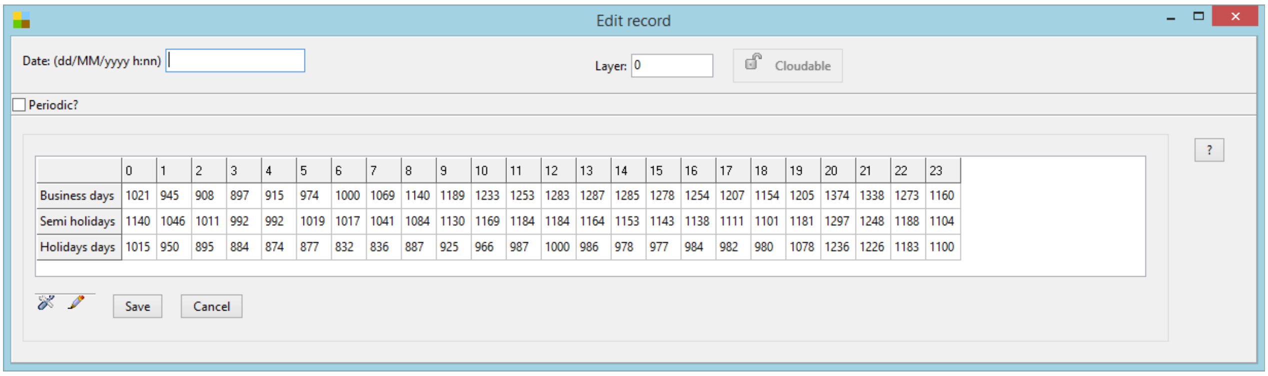
In the event of a demand supply deficit, for the first 5% a cost of 250 USD/MWh will be computed. If the deficit exceeds 5%, over the surplus with respect to 5% the first 7.5% will be computed at a cost of 400 USD/Mwh and if the deficit exceeds the sum 5% + 7.5% ,over the surplus the first 7.5% is computed at a cost of USD 1200/MW. If the deficit exceeds 5% + 7.5% + 7.5% , for the surplus and in addition to the calculations from the first three steps, a cost of 2000 USD/MWh will be computed. To be consistent in the use of the Rationing Levels, the depths added must totalize 1 (one) and the Rationing Cost must be increasing from left to right.

The Rationing Cost Multiplier selector (and the corresponding Terminal) on the right panel allows you to select a Source to index the Rationing Cost. This is useful because in long-term Rooms in which fuels have indexation, it is reasonable to index the Rationing Cost so that the system resources do not end up being more expensive than the Rationing Cost. If only more expensive resources are left in the system than the rationing, the optimizer will dispatch the rationing before those resources. This may be a desired behavior for a demand that is able to "get out" of the system when costs are high; but it is hardly the case of the main demand of the country, so care must be taken with the relationship between the Rationing Cost and resources so that the modeling fits the actual operation of the system.

3.2.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Business days	1021	945	908	897	915	974	1000	1069	1140	1189	1233	1253	1283	1287	1285	1278	1254	1207	1154	1205	1374	1338	1273	1160
Semi holidays	1140	1046	1011	992	992	1019	1017	1041	1084	1130	1169	1184	1184	1164	1153	1143	1138	1111	1101	1181	1297	1248	1188	1104
Holidays days	1015	950	895	884	874	877	832	836	887	925	966	987	1000	986	978	977	984	982	980	1078	1236	1226	1183	1100

In this Actor, the dynamic parameters work by interpolation at each time step between two dynamic parameter Records. For this to be possible, the Actor must have at least two dynamic parameter Records defined. One that begins before the start of the simulation (and optimization) and another after the end. The idea is that one Record can be placed per month (or per quarter) in which it is indicated how the power load curve changes in the year and that the simulator interpolates between the parameter Records to give a continuous variation.

A curve must be entered for each type of day. As an example, given two consecutive Records A and B, at the beginning of Record A, the demand will be the one specified in A. Internally the three curves demand is increasing (or decreasing) until the start date of the B Record. From that start date the demand is the one specified in the Record B and so on.

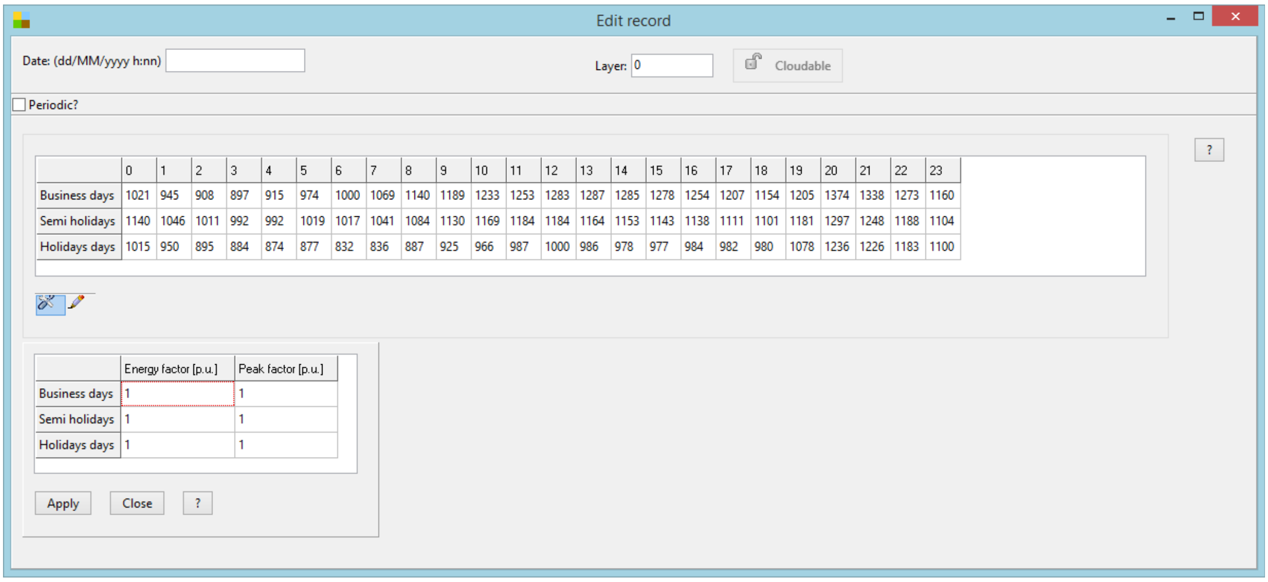
In the lower left the Record has the button which is used to "apply growth factors" to any of the hourly curves already defined. The button is used to "Import data" and overwrite the already defined time curves.

Pressing any of the two buttons displays a panel that must be closed in order to return to the form in the original condition (the “Save” or “Cancel” buttons are deactivated to finish editing the load curves).

The following describes the panels that are enabled by pressing the aforementioned buttons.

3.2.c.i Apply growth factors:

By clicking on the button “Apply growth factors” , a panel is opened at the bottom of the Record where it is possible to enter different growth factors for the energy peak (p.u.) for the 3 types of days defined in this demand, as shown in the following figure:



In the example, all the factors are with the value 1 (one) except for the holidays on which a 20% growth has been specified for energy (factor = 1.2) and 30% for the peak (factor = 1.3) . Pressing the “Apply” button will apply the factors on the load curves (If the button is pressed more than once the same factors will be applied repeatedly).

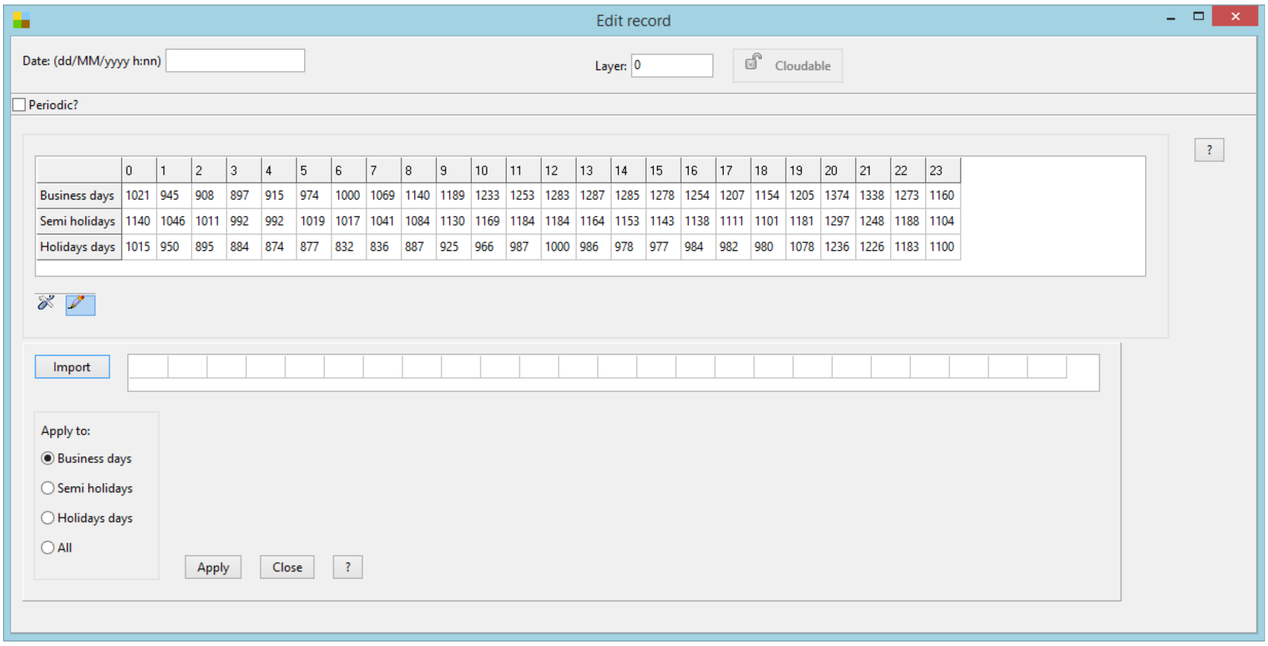
For the implementation of the algorithm that applies the factors, if the demand curve is Flat (all equal values) it only apply the energy factor ignoring that of the peak. In the case of non-Flat demands, an algorithm is used that applies the peak factor to the maximum demand hours and calculates the rest of the hours so that the new peak power minus an amount proportional to the energy difference with respect to the peak of said hour in the original load curve.

The proportionality constant is calculated to respect the specified energy growth. This algorithm does not always manage to calculate a valid load curve, since in order to respect both growth factors it can result in negative powers. If that is the case, an error message appears and the factors do not apply.

Once the factors have been applied, you must press the "Close" button to exit the growth factors application panel.

3.2.c.ii Import Data:

Clicking on the button "Import Data" opens the data import panel at the bottom of the Record as shown in the following figure:



To import 24 new values to be applied to some (or all) of the demand curves, press the “Import” button and the window for importing values will open as shown in the example in the figure. When the window opens, an empty text box appears in which the 24 values corresponding to the new demand curve must be written (or pasted from another application). In the import values window, you can specify the “decimal separator” to be able to read data from different sources.

When you click on “Import” in the import window, the values are interpreted and copied in the row of boxes to the right of the import button (it is empty in the example). After completing that row, you must select to which curve it applies, choosing the type of day with the buttons that appear under the label "Apply to:", with the options "Business days", "Semi-holidays", "Days holidays ”or“ All ”. Once the destination of the new demand curve has been selected, by pressing the “Apply” button the values will be copied on the corresponding days in the upper box.

3.2.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
P	MW	Yes	Yes	Power injected into the Node in the time post i . (as a demand it will be normally a negative value).
PD	MW	Yes	Yes	Power demand $PD=-P$ (without rationing).
PFj	MW	Yes	Yes	Rationing power dispatched in Rationing level j in time post i .
Costj	USD	Yes	Yes	Rationing Cost in Rationing level j in time post i

3.2.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds the following Control Variables:

For each Rationing Level l a Control Variable $P^i_{Rationing}$ is defined per Time Post i . This variable is the necessary rationing power and depends on the Rationing Depth in the Time Post being considered. As an example: for 20 Rationing Levels and 5 Posts, 20 Control Variables are defined.

The Actor introduces the following Restrictions on Control Variables:

For each Control Variable $P^i_{Rationing}$ a restriction is imposed that represents the maximum value that said variable can take for each Rationing Level l in each Time Post i as shown in ec.1

$$P^i_{Rationing} \leq P^i_D \cdot Depth^i_l$$

ec.1 Restriction of the Control Variable in time post i .

Where:

$P^i_{Rationing}$ Rationing power.

P_D^i : Power demand.

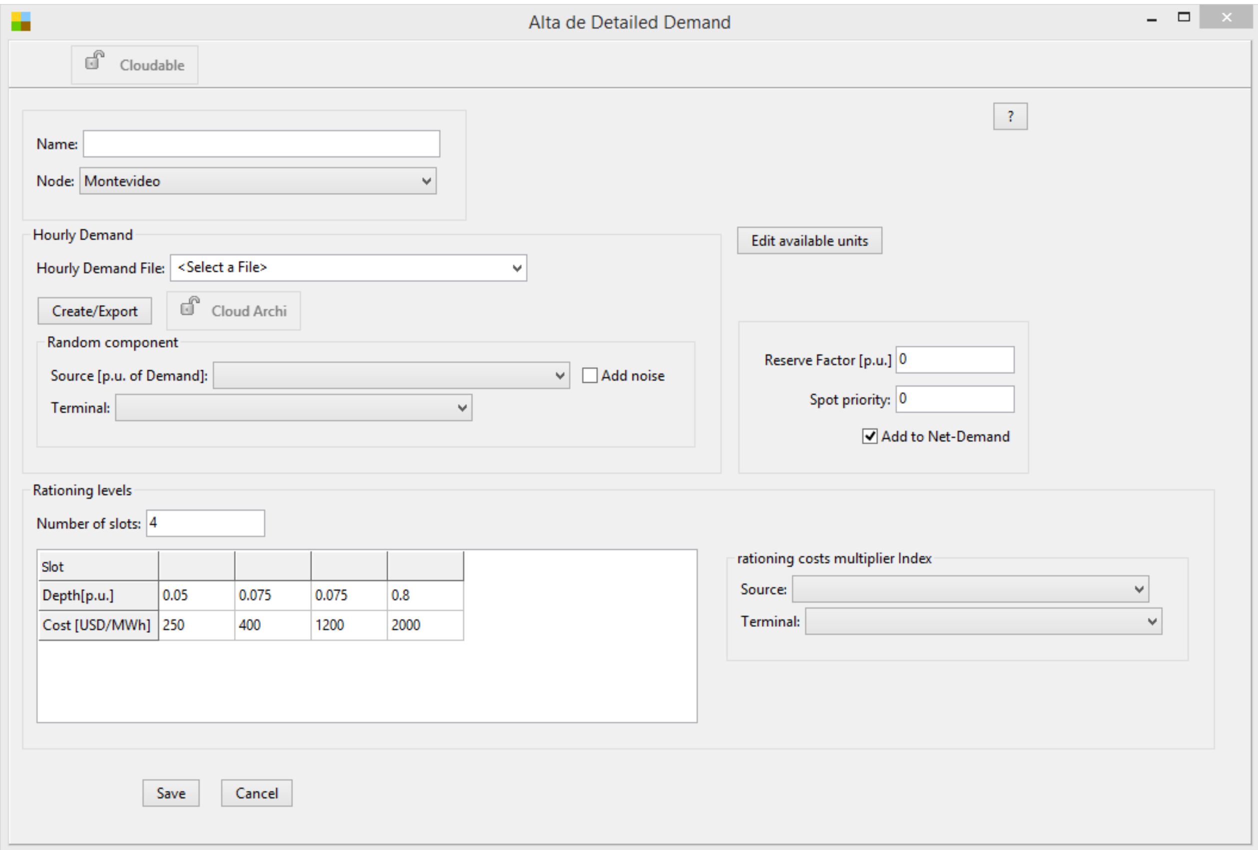
$Depth_l^i$: Rationing Level l depth.

3.3. *Detailed Demand.*

The Detailed Demand is an Actor belonging to the Demands group. The Actor represents the electrical energy consumption of the electrical system (electric power demand) based on the definition of the detailed hourly demand information for each year of the period of time to be considered. This model is the most used for programming the operation of the system in short periods (monthly, weekly, daily). For longer periods it is easier to use the demand model "Demand Generated from a Base Year and Annual Energy Vector".

3.3.a) Operation description.

The registration form of the Detailed Demand is presented below:



The Actor has the general characteristics described in the document General Characteristics of the Actors.

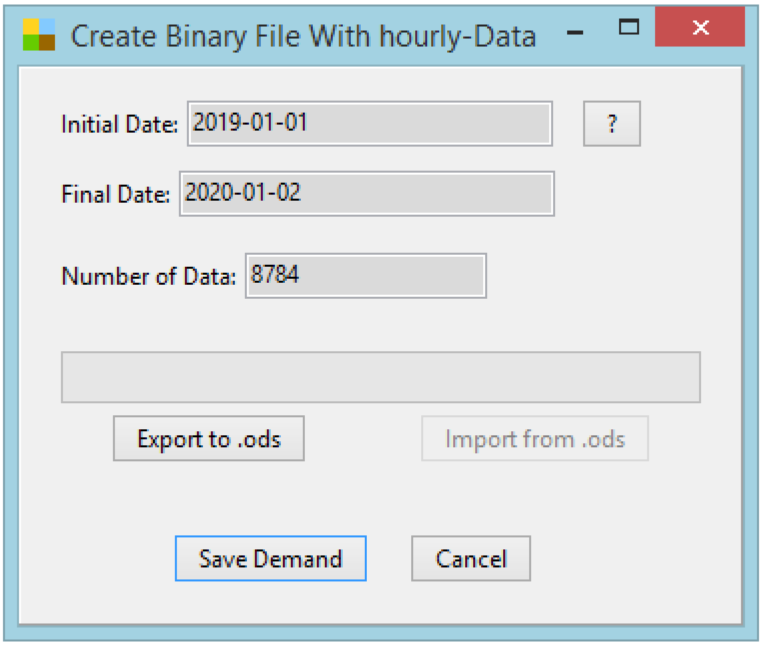
3.3.b) Static parameters.

Among the static parameters are the Name and Node of the Electric Network with which you want to associate the Actor.

3.3.b.i Hourly demand:

The characteristics of the Detailed Demand are defined in the “Hourly Demand” panel.
In the “Hourly Demand File” label, a binary file must be entered with the detailed hourly energy demand information. This file is used to model the demand for each year of the study time frame.

You can select a previously created file or press the "Create" button to create a new file. Pressing the "Create" button opens a window like the one shown in the following figure:



If a new file is being created, by default the "Initial Date" and "Final Date" appear in the Room Optimization Horizon. If for any reason you want to create a larger file, you must modify these dates to reflect it. For information purposes, the number of hours included in the specified horizon is shown in the “Number of Data” box. Note that the final date is that of the start of the next step to the last considered. In the example, the last hour considered will be the 23rd hour of January 1, 2019. Pressing the “Export .ods” button will open a spreadsheet showing the detailed description of the demand. Each Day is in a row, with the date in column "A" and each column of the following is one hour of the day. The first row shows the time of day to which the column corresponds as shown in the following figure:

	A	B	C	D	E	F	G
1		0	1	2	3	4	5
2	2019-01-01	0	0	0	0	0	0
3	2019-01-02	0	0	0	0	0	0
4	2019-01-03	0	0	0	0	0	0
5	2019-01-04	0	0	0	0	0	0
6	2019-01-05	0	0	0	0	0	0
7	2019-01-06	0	0	0	0	0	0
8	2019-01-07	0	0	0	0	0	0
9	2019-01-08	0	0	0	0	0	0
10	2019-01-09	0	0	0	0	0	0
11	2019-01-10	0	0	0	0	0	0
12	2019-01-11	0	0	0	0	0	0
13	2019-01-12	0	0	0	0	0	0

Once the spreadsheet is finished, you must save it by pressing the save button on the LibreOffice / OpenOffice toolbar and close the file (you don't need to name it or save it in a specific location). Then you must press the "Import .ods" button. Once the data is imported, you must press "Save Demand" to save it to a file. This file will be associated with the Actor you are creating, but it can also be used to create other demands in other Rooms.

In the "Random Component" panel, a Source and Termial selectors are available to assign a random source that represents the variations in demand around a preset value. The random source must generate the noise in p.u. of the demand. The value used in each time step will be the deterministic value multiplied by (1+ r) where r is the value read from the source. In the case where you do not want to use random sources, you must specify the option "None" in the box and the multiplier in this case is 1.
In addition to being able to model uncertainty in demand, the source can also be used to simulate different demand scenarios including a source with different growth.

3.3.b.ii Rationing levels:

The Rationing Levels panel indicates the number of Rationing Slots to consider. Once the number of slots has been indicated (4 in the example), the table with the Rationing Depth and Rationing Cost values is updated to allow entering the corresponding values. The levels are considered ordered from left to right.
The Depth [p.u.] is the depth of the level in the demand measurement unit and the Cost [USD / MWh] is the cost for the country economy of a failure in the supply of the demand that reaches that depth. In the example, the Rationing

Depth are 0.05; 0.075; 0.075 and 0.8 and the Rationing Costs are 250; 400; 1200 and 2000 USD / MWh respectively.

In the event of a demand supply deficit, for the first 5% a cost of 250 USD/MWh will be computed. If the deficit exceeds 5%, over the surplus with respect to 5% the first 7.5% will be computed at a cost of 400 USD/Mwh and if the deficit exceeds the sum 5% + 7.5% ,over the surplus the first 7.5% is computed at a cost of USD 1200/MW. If the deficit exceeds 5% + 7.5% + 7.5% , for the surplus and in addition to the calculations from the first three steps, a cost of 2000 USD/MWh will be computed. To be consistent in the use of the Rationing Levels, the depths added must totalize 1 (one) and the Rationing Cost must be increasing from left to right.

The Rationing Cost Multiplier index selector (and the corresponding Terminal) on the right panel allows you to select a Source to index the Rationing Cost. This is useful because in long-term Rooms in which fuels have indexation, it is reasonable to index the Rationing Cost so that the system resources do not end up being more expensive than the Rationing Cost. If only more expensive resources are left in the system than the rationing, the optimizer will dispatch the rationing before those resources. This may be a desired behavior for a demand that is able to "get out" of the system when costs are high; but it is hardly the case of the main demand of the country, so care must be taken with the relationship between the Rationing Cost and resources so that the modeling fits the actual operation of the system.

3.3.c) *Dynamic parameters.*

The actor has no dynamic parameters to specify.

3.3.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
P	MW	Yes	Yes	Power injected into the Node in the time post i . (as a demand it will be normally a negative value).
PD	MW	Yes	Yes	Power demand $PD=-P$ (without rationing).
PFj	MW	Yes	Yes	Rationing power dispatched in Rationing level j in time post i .
Costj	USD	Yes	Yes	Rationing Cost in Rationing level j in time post i

3.3.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds the following Control Variables:

For each Rationing Level l a Control Variable $P^i_{Rationing}$ is defined per Time Post i. This variable is the necessary rationing power and depends on the Rationing Depth in the Time Post being considered. As an example: for 20 Rationing Levels and 5 Posts, 20 Control Variables are defined.

The Actor introduces the following Restrictions on Control Variables:

For each Control Variable $P^i_{Rationing}$ a restriction is imposed that represents the maximum value that said variable can take for each Rationing Level l in each Time Post i as shown in ec.1

$$P^i_{Rationing} \leq P^i_D \cdot Depth^i_l$$

ec.1 Restriction of the Control Variable in time post i.

Where:

$P^i_{Rationing}$ Rationing power.

P^i_D : Power demand.

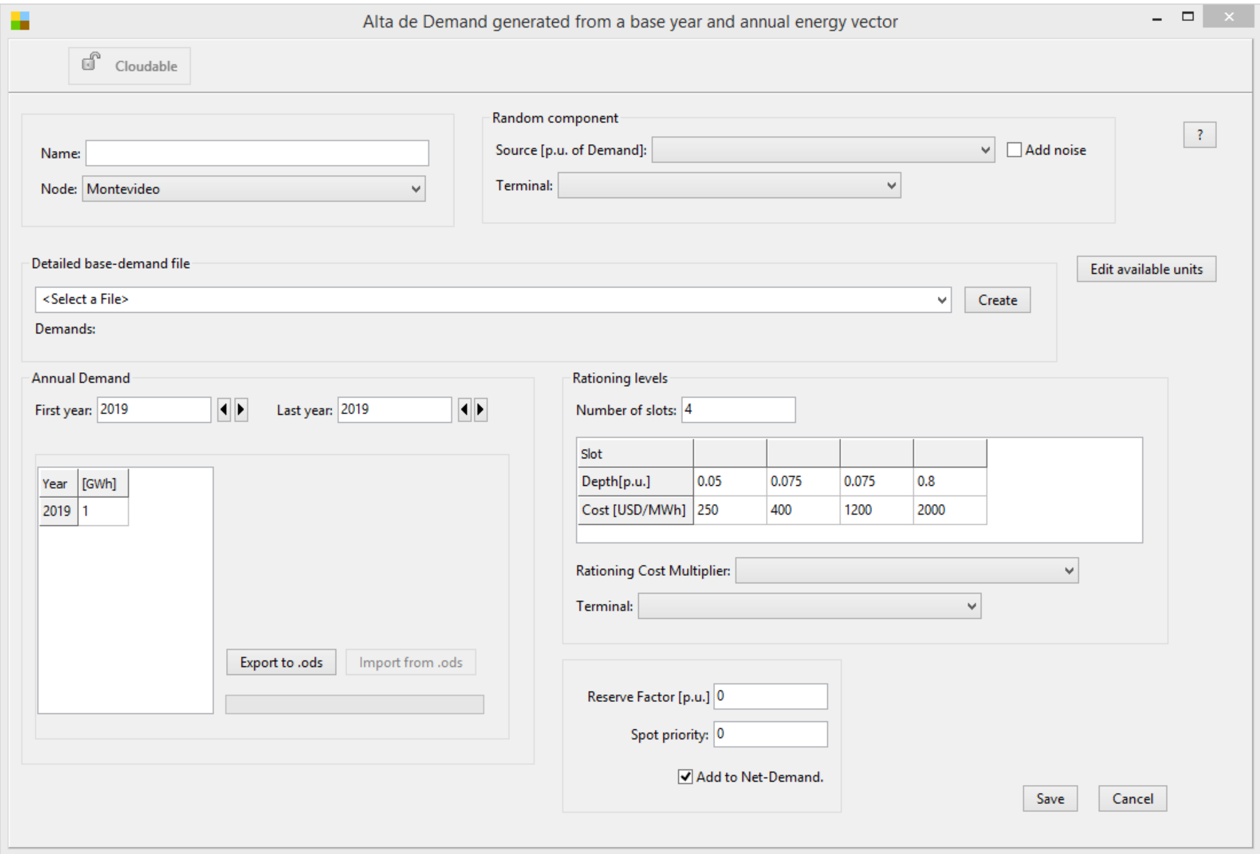
$Depth^i_l$: Rationing Level l depth.

3.4. Demand Generated from a Base Year and Annual Energy Vector.

The Demand Generated from a Base Year and Annual Energy Vector is an Actor belonging to the Demands group. The Actor represents the electrical energy consumption of the electrical system (electric power demand) based on the definition of detailed hourly demand information for a base year and the specification of the total annual energy for each year of the study time frame.

3.4.a) Operation description.

The registration form of the Demand Generated from a Base Year and Annual Energy Vector is presented below:



The Actor has the general characteristics described in the document General Characteristics of the Actors.

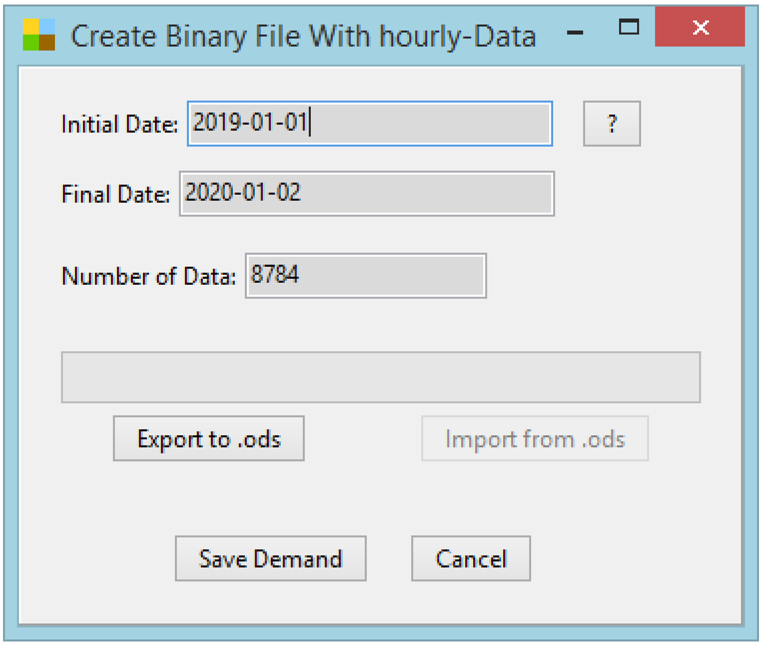
3.4.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network with which you want to associate the Actor.

3.4.b.i Detailed Base Demand file:

The characteristics of the Detailed Base Demand are defined in the Detailed Base Demand File. A binary file with the detailed hourly demand information of a base year must be entered. This file is used to model the demand of each year of the study time frame, being scaled by the necessary constants so that its annual energy is the one specified in the vector of annual energies of each year (defined in the Annual Demand panel) .

You can select a previously created file or press the "Create" button to create a new file. Pressing the "Create" button opens a window like the one shown in the following figure:



If a new file is being created, by default the "Start Date" and "End Date" appear in the Room Optimization Horizon. If for any reason you want to create a larger file, you must modify these dates to reflect it. For information purposes, the number of hours included in the specified horizon is shown in the “Number of Data” box. Note that the final date is that of the start of the next step to the last considered. In the example, the last hour considered will be the 23rd hour of January 1, 2019. Pressing the “Export .ods” button will open a spreadsheet showing the detailed description of the demand. Each Day is in a row, with the date in column "A" and each column of the following is one hour of the day. The first row shows the time of day to which the column corresponds as shown in the following figure:

	A	B	C	D	E	F	G
1		0	1	2	3	4	5
2	2019-01-01	0	0	0	0	0	0
3	2019-01-02	0	0	0	0	0	0
4	2019-01-03	0	0	0	0	0	0
5	2019-01-04	0	0	0	0	0	0
6	2019-01-05	0	0	0	0	0	0
7	2019-01-06	0	0	0	0	0	0
8	2019-01-07	0	0	0	0	0	0
9	2019-01-08	0	0	0	0	0	0
10	2019-01-09	0	0	0	0	0	0
11	2019-01-10	0	0	0	0	0	0
12	2019-01-11	0	0	0	0	0	0
13	2019-01-12	0	0	0	0	0	0

Once the spreadsheet is finished, you must save it by pressing the save button on the LibreOffice / OpenOffice toolbar and close the file (you don't need to name it or save it in a specific location). Then you must press the "Import .ods" button. Once the data is imported, you must press “Save Demand” to save it to a file. This file will be associated with the Actor you are creating, but it can also be used to create other demands in other Rooms.

In the “Random Component” panel, a Source and Termial selectors are available to assign a random source that represents the variations in demand around a preset value. The random source must generate the noise in p.u. of the demand. The value used in each time step will be the deterministic value multiplied by (1+ r) where r is the value read from the source. In the case where you do not want to use random sources, you must specify the option “None” in the box and the multiplier in this case is 1.
In addition to being able to model uncertainty in demand, the source can also be used to simulate different demand scenarios including a source with different growth.

3.4.b.ii Annual demand:

In the “Annual Demand” panel, the annual energies of the demands of the study time frame are specified.
In the First Year and Last Year boxes, indicate the first and last year of demand data that you want to consider. Depending on the period of time indicated, the table at the bottom is updated, where the annual demand in GWh must be entered for each year of the specified period. For each year, the Detailed Base Demand File data is scaled hour by hour so that the resulting annual energy matches that specified in the table.

Care should be taken that the period considered (time interval between the First Year and the Last Year) covers the time horizon that was specified to make the optimization.
Finally, there is the "Export .ods" button that opens a spreadsheet where you export the values of the table for manipulation. In this way it is possible to modify the data and then reload it to the table with the "Import .ods" button.

3.4.b.iii Rationing levels:

In the “Rationing Levels” panel you can specify the characteristics of the Rationing Levels. Once the number of slots has been defined (4 in the example), the table with the Rationing Depth and Rationing Cost values is updated to allow entering the corresponding values. The levels are considered ordered from left to right.
The Depth [p.u.] is the depth of the level in the demand measurement unit and the Cost [USD / MWh] is the cost for the country economy of a failure in the supply of the demand that reaches that depth. In the example, the Rationing Depth are 0.05; 0.075; 0.075 and 0.8 and the Rationing Costs are 250; 400; 1200 and 2000 USD / MWh respectively.

In the event of a demand supply deficit, for the first 5% a cost of 250 USD/MWh will be computed. If the deficit exceeds 5%, over the surplus with respect to 5% the first 7.5% will be computed at a cost of 400 USD/Mwh and if the deficit exceeds the sum 5% + 7.5% ,over the surplus the first 7.5% is computed at a cost of USD 1200/MW. If the deficit exceeds 5% + 7.5% + 7.5% , for the surplus and in addition to the calculations from the first three steps, a cost of 2000 USD/MWh will be computed. To be consistent in the use of the Rationing Levels, the depths added must totalize 1 (one) and the Rationing Cost must be increasing from left to right.

The Rationing Cost Multiplier selector (and the corresponding Terminal) on the right panel allows you to select a Source to index the Rationing Cost. This is useful because in long-term Rooms in which fuels have indexation, it is reasonable to index the Rationing Cost so that the system resources do not end up being more expensive than the Rationing Cost. If only more expensive resources are left in the system than the rationing, the optimizer will dispatch the rationing before those resources. This may be a desired behavior for a demand that is able to "get out" of the system when costs are high; but it is hardly the case of the main demand of the country, so care must be taken with the relationship between the Rationing Cost and resources so that the modeling fits the actual operation of the system.

3.4.c) *Dynamic parameters.*

The actor has no dynamic parameters to specify.

3.4.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
P	MW	Yes	Yes	Power injected into the Node in the time post i . (as a demand it will be normally a negative value).
PD	MW	Yes	Yes	Power demand $PD=-P$ (without rationing).
PFj	MW	Yes	Yes	Rationing power dispatched in Rationing level j in time post i .
Costj	USD	Yes	Yes	Rationing Cost in Rationing level j in time post i

3.4.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds the following Control Variables:

For each Rationing Level l a Control Variable $P^i_{Rationing}$ is defined per Time Post i . This variable is the necessary rationing power and depends on the Rationing Depth in the Time Post being considered. As an example: for 20 Rationing Levels and 5 Posts, 20 Control Variables are defined.

The Actor introduces the following Restrictions on Control Variables:

For each Control Variable $P^i_{Rationing}$ a restriction is imposed that represents the maximum value that said variable can take for each Rationing Level l in each Time Post i as shown in ec.1

$$P^i_{Rationing} \leq P^i_D \cdot Depth^i_l$$

ec.1 Restriction of the Control Variable in time post i .

Where:

$P^i_{Rationing}$ Rationing power.

P^i_D : Power demand.

$Depth^i_l$: Rationing Level l depth.

4. Wind Group.

For the purposes of this document, we define a wind farm as a set of one or more wind turbines that have the same characteristics.

The group of Actors that belong to the “Wind” tab are those used to model the wind farms of the electrical system. It is possible to create the following types of wind farms: “Wind Farm” and “Vxy Wind Farm”

The main difference presented by these two actors is that the actor “Wind farm vxy” takes into account the direction of incidence of the wind and its intensity, while the actor “Wind farm” only takes into account the intensity.

Each wind farm must be assigned to a Node in the electrical system where it injects the energy it generates. The availability of the generating units will be given by a fault / repair model specifying the probability of finding the “available” unit and the average repair time in hours.

In SimSEE, the wind actors are modeled considering that the variable cost of generation for the dispatch is zero, but there is the possibility of making payments for the energy delivered and for the available energy. The available energy may not be dispatched if the marginal of the system is zero and the demand of the system is limited and there is no possibility of exporting the energy.

In the editing forms, there is an **"Edit Available Units"** button that allows you to access the form to edit the number of wind turbines in the park during the study period. Also with this application it is possible to plan the scheduled maintenance as with the rest of the Actors.

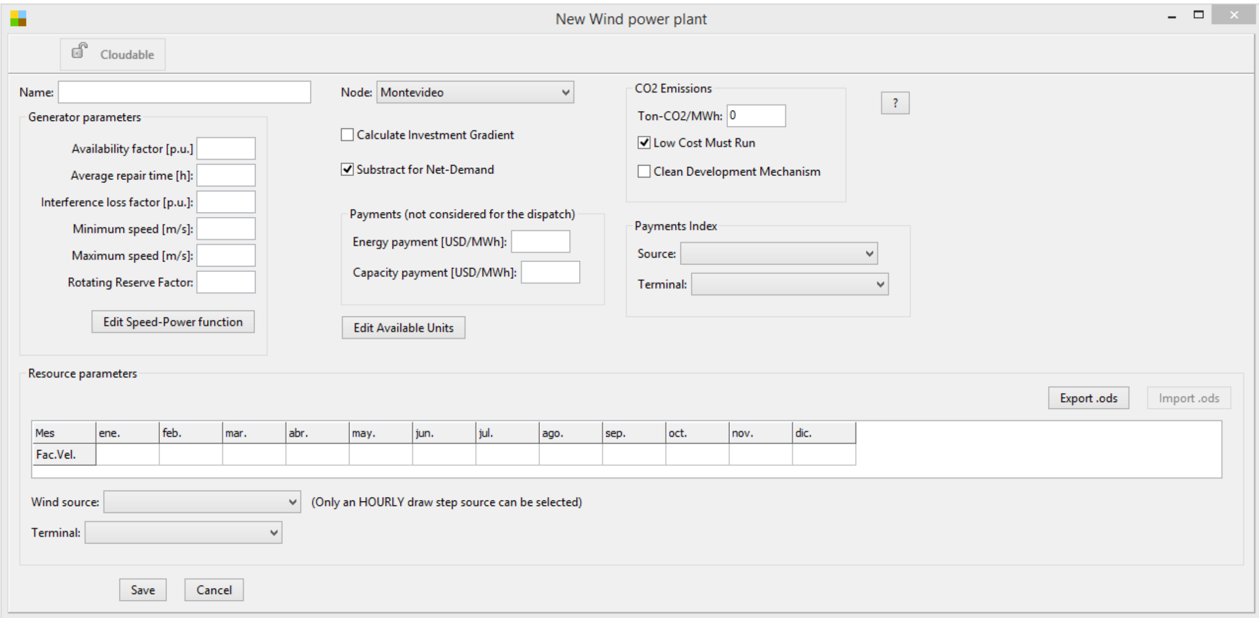
TParqueEolico TParqueEolico_vxy

4.1. Wind Power Plant.

The Wind Power Plant is an Actor that belongs to the Wind Group. The Wind Power Plant model supports the definition of a Power-Speed function of a typical wind turbine. The Power-Speed curve can also correspond to the total power of the powerplant divided by the amount of wind turbine units.

4.1.a) Operation description.

The registration form of the Wind Power Plant is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

4.1.b) *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

In the "Generator Parameters" panel you must specify:

- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Interference loss factor: The loss is specified in per unit of effective speed in the plant due to interference between the mills. For the calculation of

the instantaneous power of a generating unit, the hourly mean wind speed is multiplied by the speed factor of the month (Fac.Vel) and by the interference loss factor before entering the speed in the curve " Power-Speed ".

- Minimum/maximum speed: It is the range in m/s over which you want to edit the "Speed-Power" curve. The amount of discretizations (speed-power points) to be edited is specified within the pop-up window in the "Edit Speed-Power curve" button (See Fig. 2). In the left column, the speeds corresponding to the points defined by the discretization appear and for each of these points it is necessary to specify the power of the generator in MW. The "Export .ods" button allows you to export the table to a spreadsheet for editing. With the "Import .ods" button, the modified data is imported.

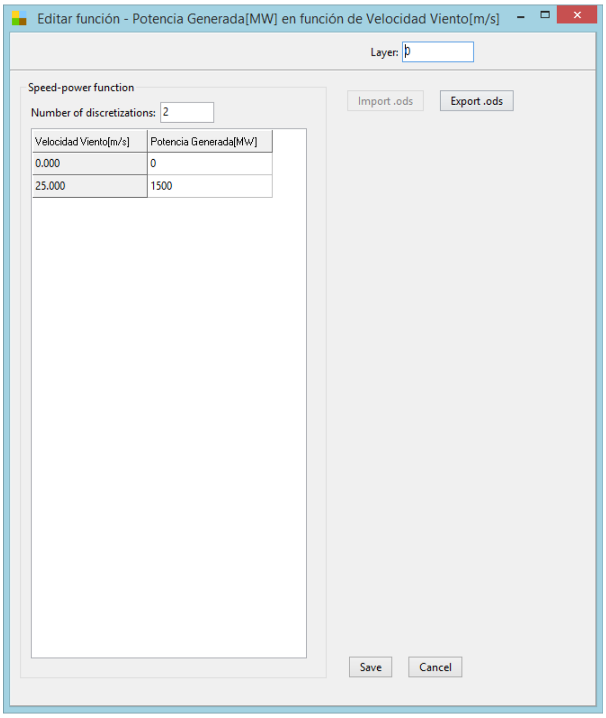


Fig. 2: Speed-Power Curve Editor.

- Rotating reserve factor: Factor in p.u that multiplies the maximum power generated by the Actor for each time post to determine the contribution of the Actor to the Rotating Reserve.

In the "Resource Parameters" panel you must specify:

- Table of values "Fac.Vel.": Monthly Speed Factors that directly multiply the data coming from the source of wind speeds. It allows to account for the seasonal variation of the wind speed if it was not considered in the source of winds used. The table of monthly values can be edited directly in the form or exported to a spreadsheet, edited and then imported using the “Export .ods” and “Import .ods” buttons.

- Wind Source: A Random Source (of hourly step) and a wind terminal in m/s must be selected to made an integration of the energy received in each time post to take into account within the time step. The passage of the hourly powers to the average power values per post is carried out through the mechanism of “summary in sub-sampled enslavement” of the Sources in SimSEE (See section 1.5 of Volume 2 “Sources” of this same series of manuals).

4.1.c) *Dynamic parameters.*

The actor does not have dynamic parameters.

4.1.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
VSpeed	m/s	Yes	Yes	Wind speed seen by wind turbines.
NAvailableUnits	u	No	Yes	Number of available units in the time post.

4.1.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 2 Control Variables:

- P_i : Power injected to the node.
- P_{RRi} : Power contributed to the Rotating Reserve.

The Actor adds the following constraints to the optimization problem:

- Node power restriction.
- Balance reserve of the node restriccion (if a reserve factor greater than zero is specified).
- Restriction of nominal power limit (if a reserve factor greater than zero is specified): $P_i + P_{RRi} \leq PMax_i$ for each time post i . Being $PMax_i$ the maximum generable power per time post.
- Power on restriction to generate rotating reserve (if a reserve factor greater than zero is specified): $P_i \geq 1/100 . P_{RRi}$ for each time post i .

4.2. Wind Power Plant vxy.

The Wind Power Plant vxy is an Actor that belongs to the Wind Group.
This wind power plant model allows the incorporation of wind direction information (in addition to wind speed) to obtain a better representation of the operation of the power plant.

4.2.a) Operation description.

In order to describe the operation of the plant for each wind direction, it is necessary to connect a wind source capable of generating the two velocity components "vx" (horizontal, positive with wind from the East) and "vy" (vertical, positive with wind from the north).

Fig. 1 shows the Wind Rose with the 16 discretized positions ot the wind direction, for the purposes of entering information.

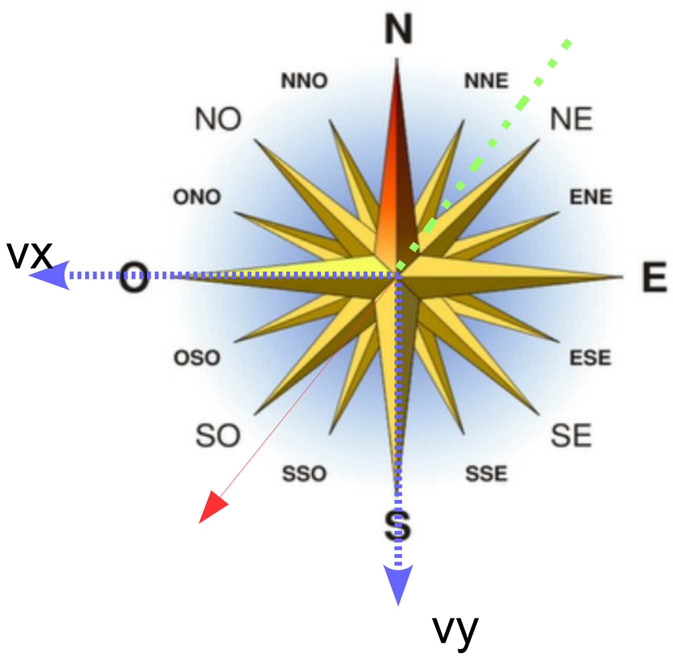


Fig. 3: Wind rose and sign convention.

The wind direction is, by convention of use, the downwind direction. Thus, if it is said that, for example, the interference speed loss factor is 0.8 for the E (East) direction it will be indicated that this factor is applicable when the wind blows in the East -> West direction.

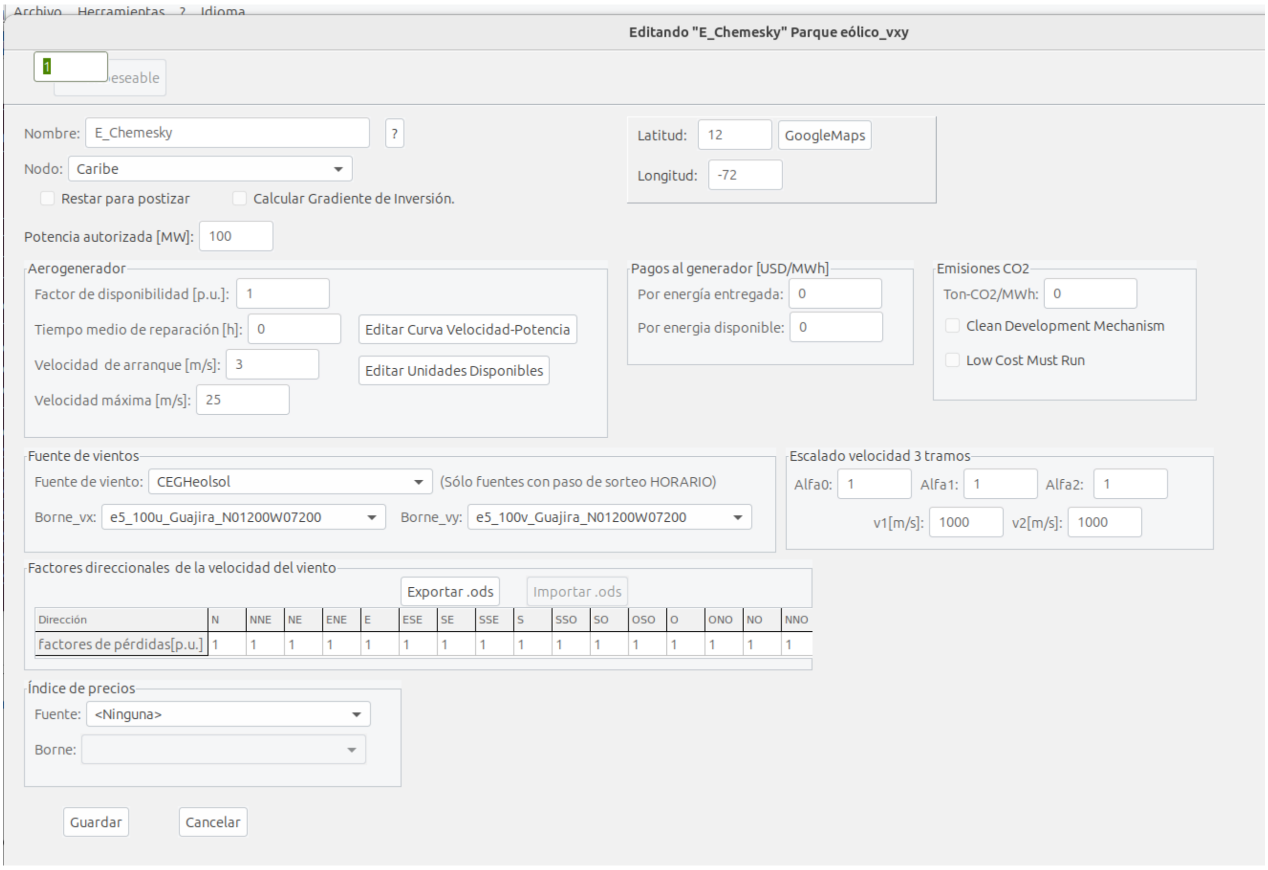
SimSEE

Wind speeds (vx, vy) are considered according to the axes marked in blue in the figure. As an example, a velocity with $v_x = 1.0$ m/s , $v_y = 1.1$ m/s is shown in the figure (red vector). The velocity module will be $\sqrt{v_x^2 + v_y^2}$ and the wind direction (green dotted line opposed to the red vector) will be between NNE and NE.

The model allows to represent a power plant with different level of detail according to the available information. If you have a complete design of the plant, you can enter Speed-Power curves per direction calculated as the characteristic curves of the wind farm (by detailed simulation or by direct measurement) divided by the number of units of the power plant. In that case you can put in 1 (one) the factors of losses per direction and the speed multiplier.

If there is no specific information about the power plant to be modeled, one option is to load in the Speed-Power curves, the same curve in all directions (that of a wind turbine) and use the loss factors per direction to create a design depending on the Wind Rose of the geographical location of the facility, in order to achieve lower losses to the more energetic ranges.

The registration form of the Wind Power Plant vxy is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

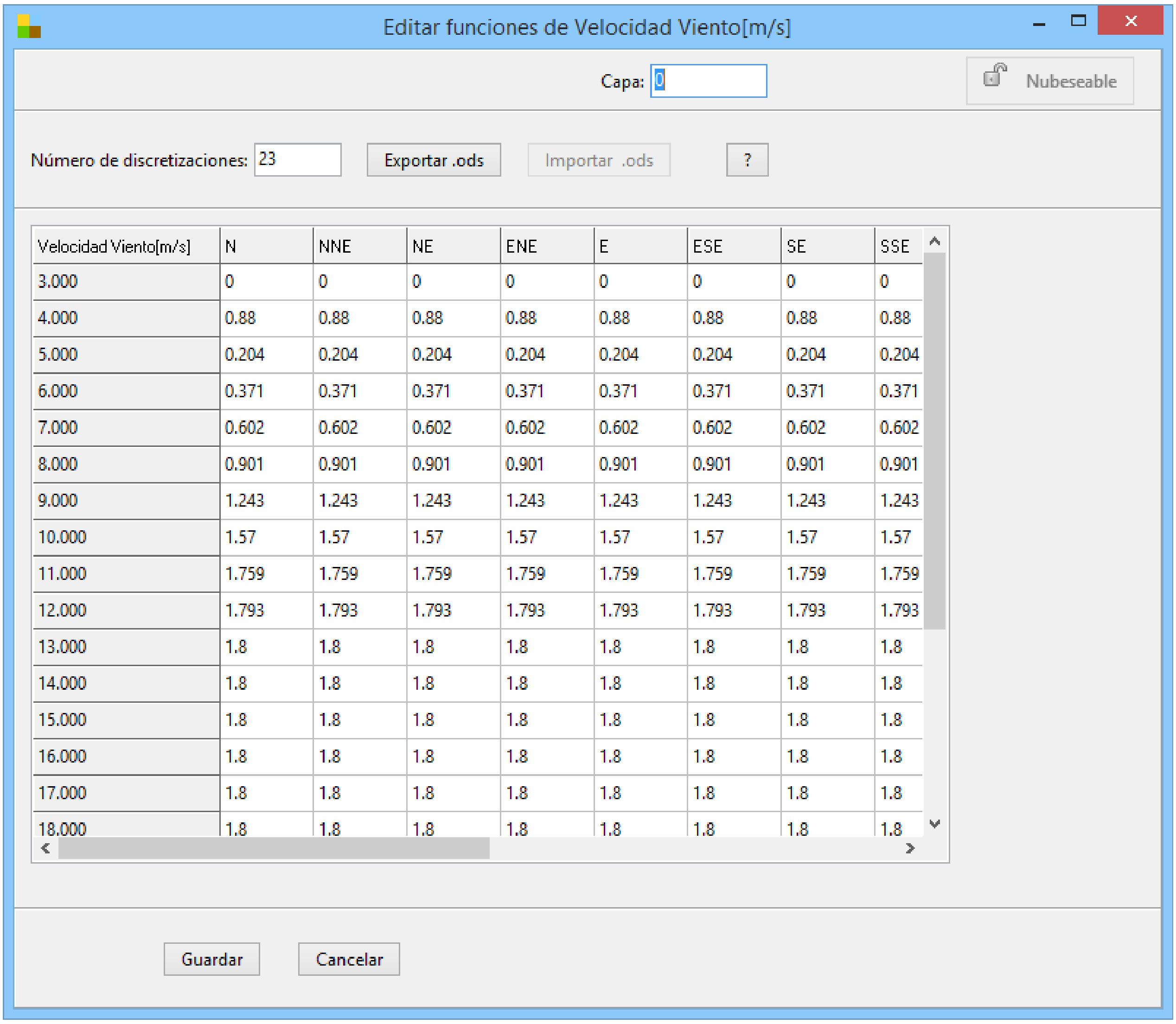
4.2.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network with which you want to associate the Actor.

In the "Wind turbine" panel you must specify:

- Availability factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- Average repair time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Cut-in speed and cut-out speed: The cut-in speed is the minimum wind speed at which the turbine blades overcome friction and begin to rotate. The cut-out speed is the speed at which the turbine blades are brought to rest to avoid damage from high winds. These two speeds define the range for the discretization of the Speed-Power curves. The information is

entered in the form that opens when you press the "Edit Speed-Power Curve" button as shown in Fig. 4. This form allows you to edit the typical Speed-Power curves of a wind farm power genertaing unit according to the downwind direction. Each column contains the characteristic curve of a power generating unit according to a wind direction.



Velocidad Viento[m/s]	N	NNE	NE	ENE	E	ESE	SE	SSE
3.000	0	0	0	0	0	0	0	0
4.000	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
5.000	0.204	0.204	0.204	0.204	0.204	0.204	0.204	0.204
6.000	0.371	0.371	0.371	0.371	0.371	0.371	0.371	0.371
7.000	0.602	0.602	0.602	0.602	0.602	0.602	0.602	0.602
8.000	0.901	0.901	0.901	0.901	0.901	0.901	0.901	0.901
9.000	1.243	1.243	1.243	1.243	1.243	1.243	1.243	1.243
10.000	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57
11.000	1.759	1.759	1.759	1.759	1.759	1.759	1.759	1.759
12.000	1.793	1.793	1.793	1.793	1.793	1.793	1.793	1.793
13.000	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
14.000	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
15.000	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
16.000	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
17.000	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
18.000	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

Fig. 4: Power Speed Curve Editor according to direction.

The amount of discretization points according to the speed in the range specified by the parameters "Start speed" and "Maximum speed" is set in the "Number of Discretizations" box (23 in the example). The "Export .ods" button allows you to export the table to a spreadsheet and the "Import .ods" button allows you to import the data once the edition is finished in the spreadsheet. The "Save" and "Cancel" buttons must be used to close the editing form by saving the changes made or ignoring them respectively.

In the panel "Wind source" you must specify:

- Wind Source: It is the wind source in m/s and it must be an hourly draw step (in the combobox only the hourly step sources are shown). The Terminal that generates the speed in the vx direction (from East to West) and in the vy direction (from North to South) must be selected.
- Escalado velocidad 3 tramos: Describe una curva de afectación del módulo de la velocidad de la fuente por una curva lineal de tres tramos:

$$\begin{array}{l} v_{Fuente} < v_1 \rightarrow v_{Parque} = \alpha_0 v_{Fuente} \\ v_{Fuente} \in (v_1, v_2) \rightarrow v_{Parque} = \alpha_0 v_1 + \alpha_1 (v_{Fuente} - v_1) \\ v_{Fuente} > v_2 \rightarrow v_{Parque} = \alpha_0 v_1 + \alpha_1 (v_2 - v_1) + (\alpha_2 v_{Fuente} - v_2) \end{array} \quad , \quad (4)$$

In the “Directional factors of wind speed” panel, specify:

Loss factors: For each wind direction the loss factors in p.u to be applied to the wind speed module are defined. The “Export .ods” and “Import .ods” buttons allow you to export the loss factor table to a spreadsheet, edit them and then import them. In case of not having the detailed power curve of the wind farm (a power curve for each incident wind direction sector) these factors can be used to represent the losses from the plant's internal trails.

4.2.c) *Dynamic parameters.*

The actor does not have dynamic parameters.

4.2.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
VSpeed_x	m/s	Yes	Yes	Wind speed seen by wind turbines in the “x” direction (positive with wind from the East).
VSpeed_y	m/s	Yes	Yes	Wind speed seen by wind turbines in the “y” direction (positive with wind from the North).
NAvailableUnits	u	No	Yes	Number of available units in the time post.

4.2.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 1 Control Variable:

- P_i : Power injected to the node.

The Actor adds the following constraints to the optimization problem:

- Node power restriction.

5. Solar Group.

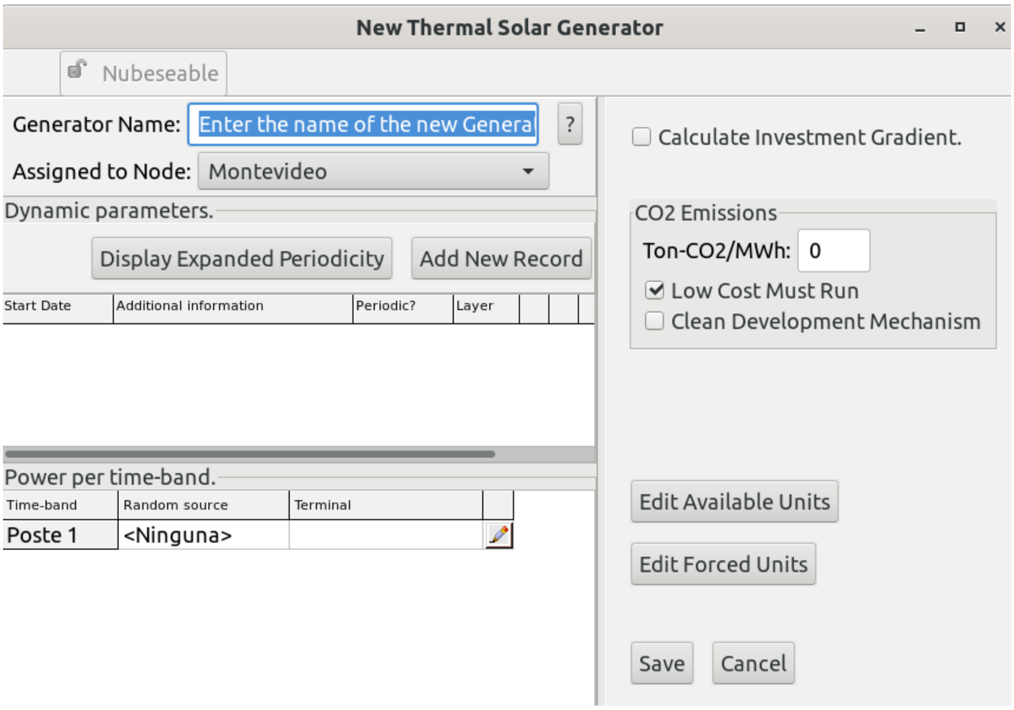
This group contains the models of solar thermal generator and photovoltaic solar generator.
(TSolarTermico, TSolarPV)

6. Thermal Solar Generator.

The Solar Thermal Generator is an Actor that belongs to the Solar Group. This model is applicable to power plants based on heating of water based on solar energy and generation based on the expansion of water vapor in a steam turbine that serves as a driving force to an electric generator. The control unit can be composed of one or more units with a technical minimum and with dispatch per time band (Poste).

6.1. *Function description.*

The registration form of the Solar Thermal Generator is presented below:



It must specify the Name and Connection Node of the Electricity Network, if the Investment Gradient is calculated, the parameters for the calculation of CO2 Emissions, the Available Units and the Forced Units similar to the rest of the Actors generators Additionally, the Actor has the Powers per Post panel where the average power received by the Actor for each Post of the time step must be specified.

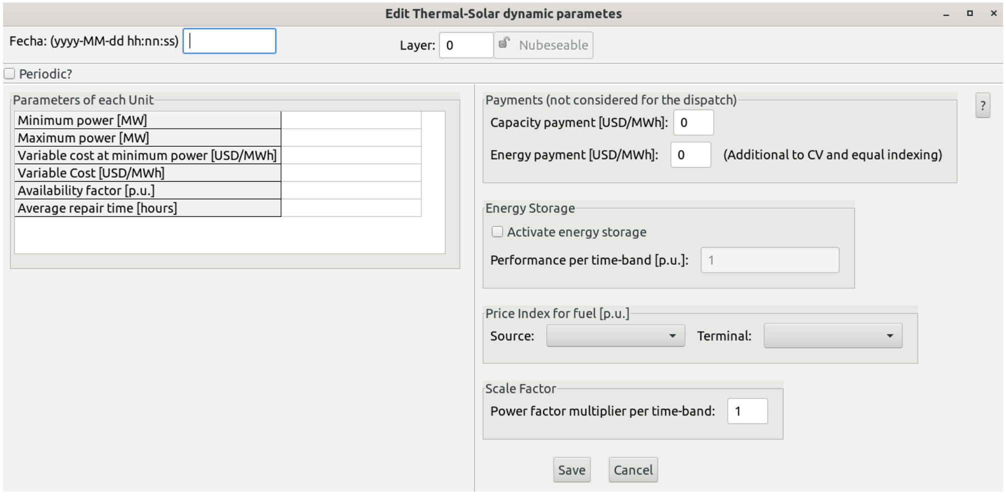
6.2. *Static parameters.*

The static parameters are the Name and Node of the Electric Network to which you want to associate the Actor.

The "Power by posts" table allows you to select random sources that directly model the average power in MW per plant from the solar collectors for each of the Posts.

6.3. Dynamic parameters.

The form that allows you to create/edit the dynamic parameters is shown below:



The dynamic parameters are:

- Minimum Power: It is the minimum power value in MW to which the generator can be operated stably when it is coupled to the power grid.
- Maximum Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electricity Network.
- Variable cost at minimum power: It is the variable cost of production in USD/MWh when the unit operates at the technical minimum. This cost can be indexed to the Fuel Price Index.
- Variable cost: It is the variable cost of production in USD/MWh for the incremental generation above the technical minimum. This cost can be indexed to the Fuel Price Index.
- Availability factor: It is the availability factor in p.u. and determines what percentage of the time said Actor is in service and operational outside the scheduled maintenance windows.
- Average repair time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.

The aforementioned variable costs are for use in the case where the plant uses a fuel complementary to the energy received from the sun as a complement in its thermal cycle. For example, it could burn biomass or an oil derivative. In order to index these costs, the source "Fuel price index [p.u. of the price]".

The parameters associated to the energy store to be specified are:

- Activate energy storage: This checkbox allows you to model in a very simplified way the possibility of storing solar heat to be used during peak demand hours. By checking this box, the field "Performances per post [p.u.]" is enabled.

- Performance per time-band: Performance in p.u. to be applied to each time-band by the transfer of the hours of greatest solar radiation to the hours to which the post corresponds. A performance of 1.0 indicates that the time-band is mainly formed by hours of good solar radiation and therefore if the energy is consumed in that time-band there will be no storage losses. A low performance indicates that that, at the corresponding time-band, the plant does not receive direct radiation from the sun and that it is distant in hours from the hours of higher radiation and consequently the storage of energy in the hours of greater solar radiation for consumption in the that time-band has associated energy losses.

The "Scale Factor" parameters to be specified are:

- Power multiplier factor per time-band: Factor in p.u. which multiplies the average power received by the solar collectors ("Power per time-band"). This factor allows different solar collector surfaces to be considered for a given set of sources.

6.4. Variables published for SimRes.

The Actor allows publishing the following variables by post or time step:

Name	***Units***	***Time-banded***	***SR3***	***Description***
cdp	USD	No	Yes	Costs incurred for power generation.
IngresoPorDisponibilidad	USD	No	Yes	Payments received by the actor for availability.
IngresoPorEnergía	USD	No	Yes	Additional payments received by the actor for the energy dispatched.
P	MW	Yes	Yes	Power injected to the node.
ReservaRotante	MW	No	No	Rotating Reserve
cv_Spot	USD/MWh	No	No	Variable Cost for Spot Price computation.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the Power limit constraint.
ParticipacionSCS	USD	No	No	Participation in the System Reliability Service.
ForzamientoSCS	USD	No	No	Forcing in the System Reliability Service
E*cmg	USD	No	Yes	Energy valued at the Marginal Generation Cost (If investment gradient comutation is selected).
GradInv	-	No	Yes	Investment Gradient (If investment gradient comutation is selected)
Costo	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NMaqsDespachadas	u	Si	Si	Number of dispatched machines.

c0	USD/h	No	Si	Cost per machine to be operating at the technical minimum.
cv	USD/MWh	No	Si	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
cve	USD/MWh	No	Si	Payment for additional energy to the cv, affected by the price index.
PMax	MW	Si	Si	Maximum power available.
NMaquinasDisponibles	u	NO	Si	Number of machines available.
PMediaDespachada	MW	No	No	Average power dispatched in the time-step.
MaxNMaqsDespachadasEnElPaso	u	No	No	Maximum number of units dispatched in the time-step.

6.5. Variables Status, Control and Restrictions.

The Actor does not add Status Variables to the system.

The Actor adds two Control Variables for each time-band i :

- A_i : Switching on the control panel (ON / OFF = 1/0).
- p_i : Power dispatched above the technical minimum in MW.

In addition to participating in the power balance restriction imposed by the Node to which it connects, the Actor adds the following restrictions to the optimization problem:

- Restriction imposed by the coupling variable for each time-band i :
  - If there is an energy store: $p_i \leq A.(Pmáx-Pmín)$.
  - If there is no energy store: $p_i \leq A.min[(Pmáx-Pmín),(Pr_i-Pmín)]$.

Being Pr_i the power received by the generator due to solar irradiation.

- If there is an energy store, it must be fulfilled that the sum of the energy generated affected by the performance of each time-band (ren_i) must be less than that received by the collector in the time step ($EMaxPaso$):

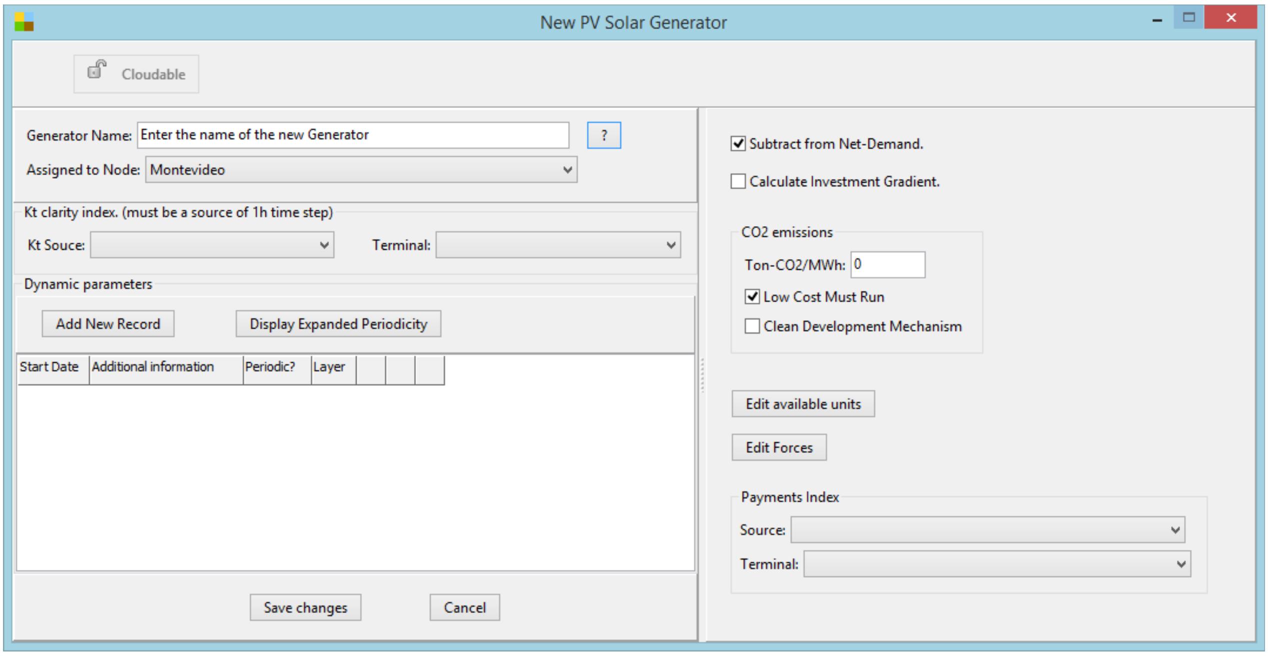
$$\sum_{k=1}^{NPostes} \frac{p_i+A_{i.}Pmin}{ren_i}.DurPoste_i=EmaxPaso$$

6.6. PV Solar Generator.

The PV Solar Generator is an Actor that belongs to the Solar Group. The Solar PV generator is designed to model solar photovoltaic powerplants.

6.6.a) Operation description.

The registration form of the PV Solar Generator is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

6.6.b) *Static parameters.*

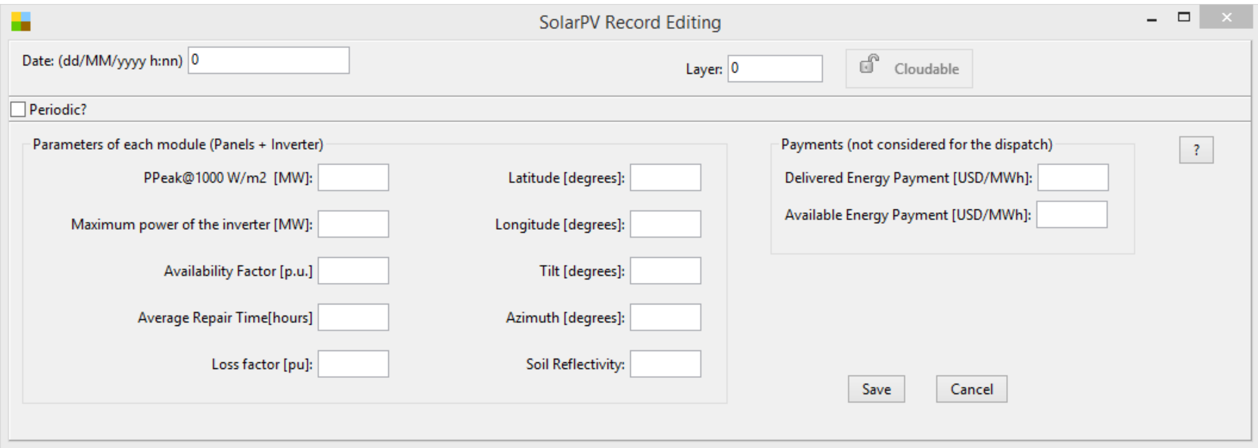
The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor, and the Kt clarity index.

The kt clarity index allows to select the Kt Source and Terminal that generates the cloudiness index Kt. This value of Kt is used to calculate solar radiation incident according to the location of the panel, the time and day of the year; taking into account the stellar geometry and the angle of placement of the solar panels. The selected Kt source must be of step time.

6.6.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The parameters of each module (Panels + Inverter) to be specified are:

- PPeak@1000 W/m²: It is the maximum Power in MW that the modules can generate under an irradiance of 1000 W/m².
- Maximum Power of the inverter: It is the Maximum Power in MW of the Inverter.
- Availability Factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- Average Repair Time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Loss factor: It is the overall loss factor of the module in p.u. which allows to calculate the available energy based on the energy received by the panel. It includes ohmic losses, losses by the transformer and inverter of the module.
- Latitude, Longitude: Geographic coordinate system in degrees used to determine the position of the panels.
- Tilt: Corresponds to the angle in degrees of elevation that the panel has with respect to a horizontal plane.
- Azimuth: Corresponds to the angle in degrees from the north where the panel is rotated.

- Soil Reflectivity: It is the Factor in p.u. used to estimate the diffuse component of the irradiation reflected by the ground.

6.6.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
ClarityIndex	p.u.	No	No	Clarity index
Irradiance_p_tilt	kWh/m2	No	No	Irradiance in tilt plane.
Irradiance_p_horizontal	kWh/m2	No	No	Irradiance in horizontal plane.

6.6.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 1 Control Variables:

- P_i : Power injected to the Node.

7. Thermal Group

A thermal generator is a generator that uses a heat source to generate steam or hot gases to expand in a turbine. Examples of these types of generators are steam boiler plants (fueled by fuel oil, diesel, biomass, coal, nuclear) and aeroderivated turbines that expand combustion gases directly into the turbine, such as turbines that burn natural gas or gasoil. Another example of thermal generators are combustion engines burning fuel oil, diesel, natural gas, biofuels, etc.

In Fig.5 the different types of thermal generators that can be created in SimSEE are presented

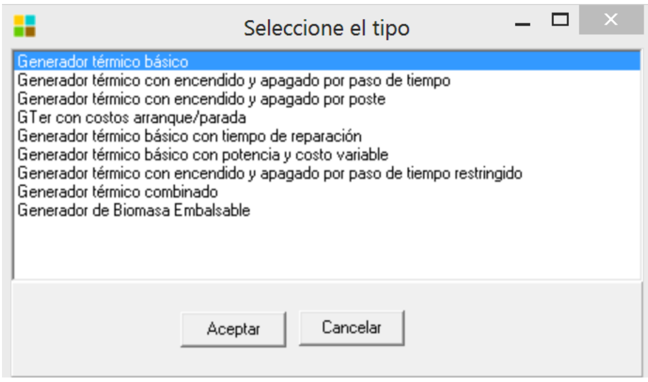


Fig. 5: Thermal generators

(TGTer_Basico,
TGTer_OnOffPorPaso,
TGTer_OnOffPorPoste,
TGTer_ArranqueParada,
TGTer_Basico_TRep,
TGTer_Basico_PyCVariable,
TGTer_OnOffPorPaso_ConRestricciones,
TGTer_Combinado

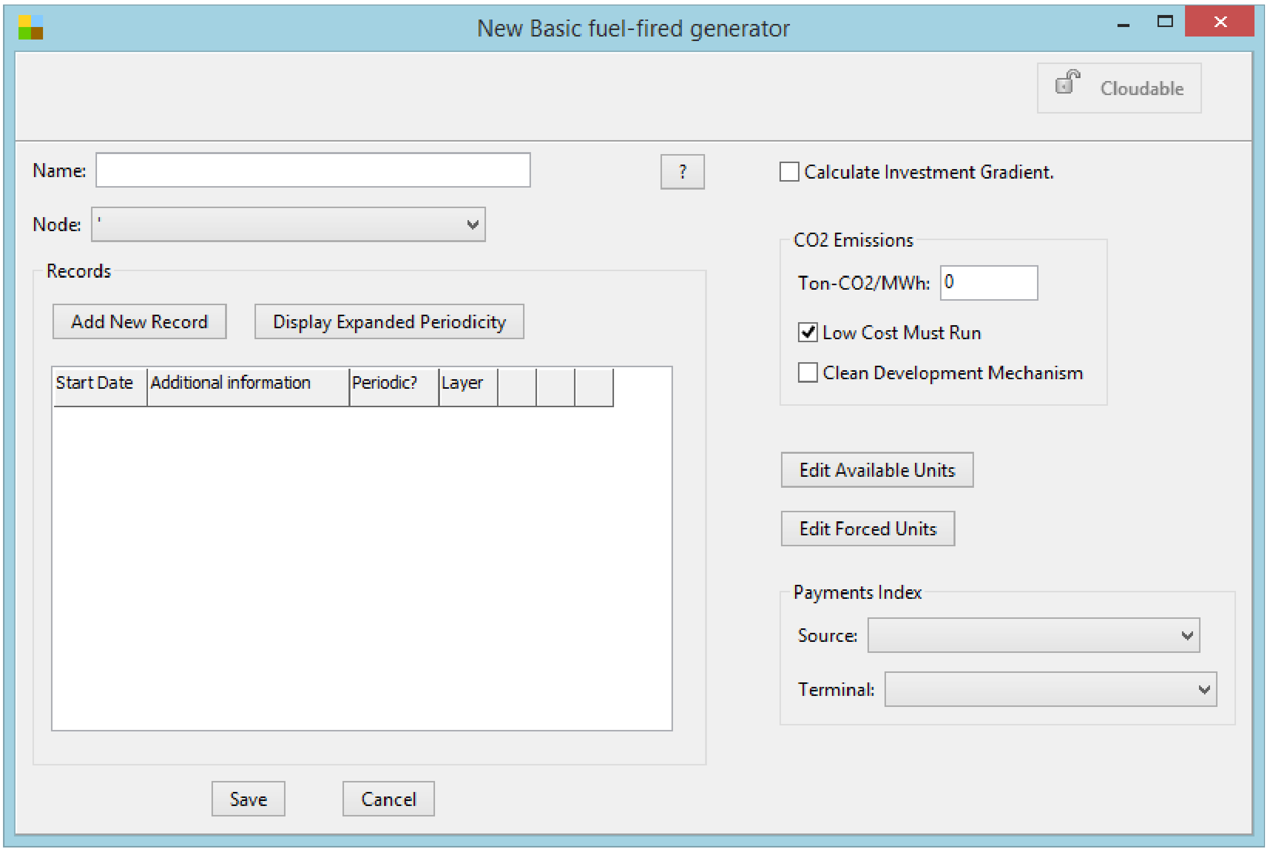
Nuevos a documentar de CERO:
TBiomasaEmbalsable
TGTer_combinado_horario (Ver documento Vanina).
)

7.1. *Basic Fuel-fired Generator.*

The Basic Fuel-fired Generator is an Actor that belongs to the Thermal Group. The Actor models the thermal generators in the simplest way. In this Actor the technical minimums are not considered and the cost of the assigned MWh is independent of the generator operating point.

7.1.a) Operation description.

The registration form of the Basic Fuel-fired Generator is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

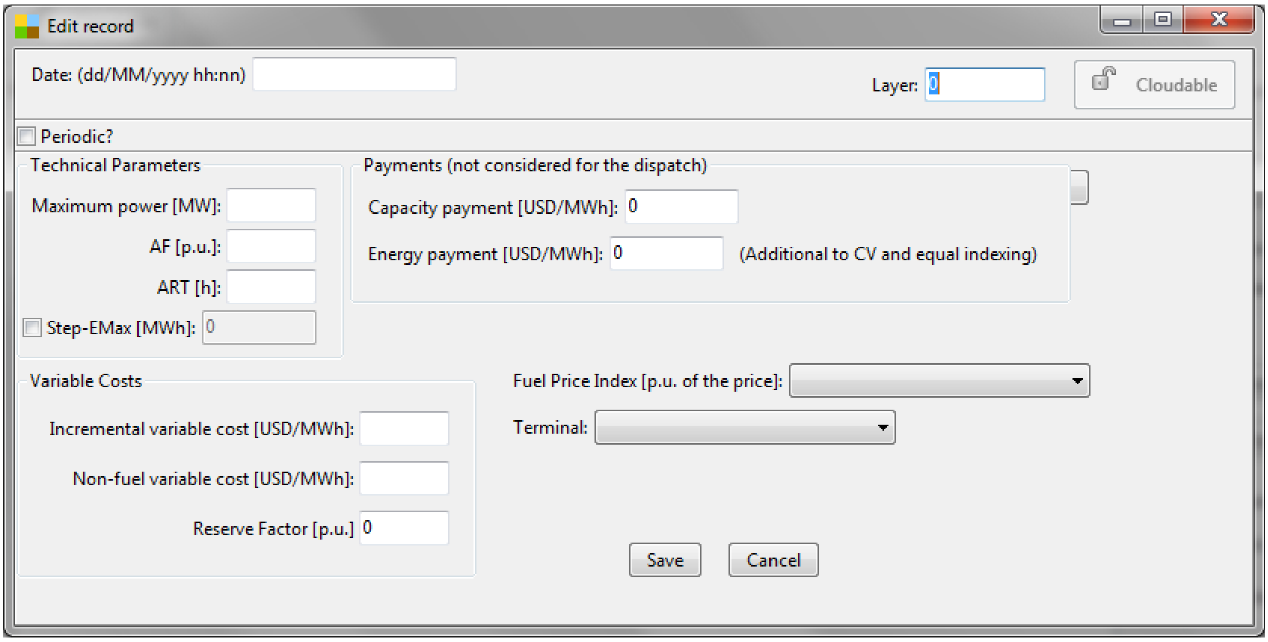
7.1.b) *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

7.1.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- Maximum power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Step-Emax: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.
-

The "Variable Costs" panel defines:

- Incremental variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.

- Non-fuel variable cost: It is the variable cost of production in USD/MWh that does not depend on the cost of the fuel used (e.g., operation and maintenance costs). This cost cannot be indexed to a price index.

7.2. Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
CVe	USD/MWh	No	No	Payment for additional energy to the C.V., affected by the price index.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time post.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
NForcedUnits	u	Yes	No	Number of forced units.
PMaxAvailable	MW	Yes	Yes	Maximun available power.

7.3. State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 1 Control Variable per time post i :

- P_i : Power output.

In Fig. 1 is plotted the cost $Cost_i$ in USD/h associated with the fuel consumption of the Actor according to the power dispatched in the time post i. The cost is defined by ec.1.

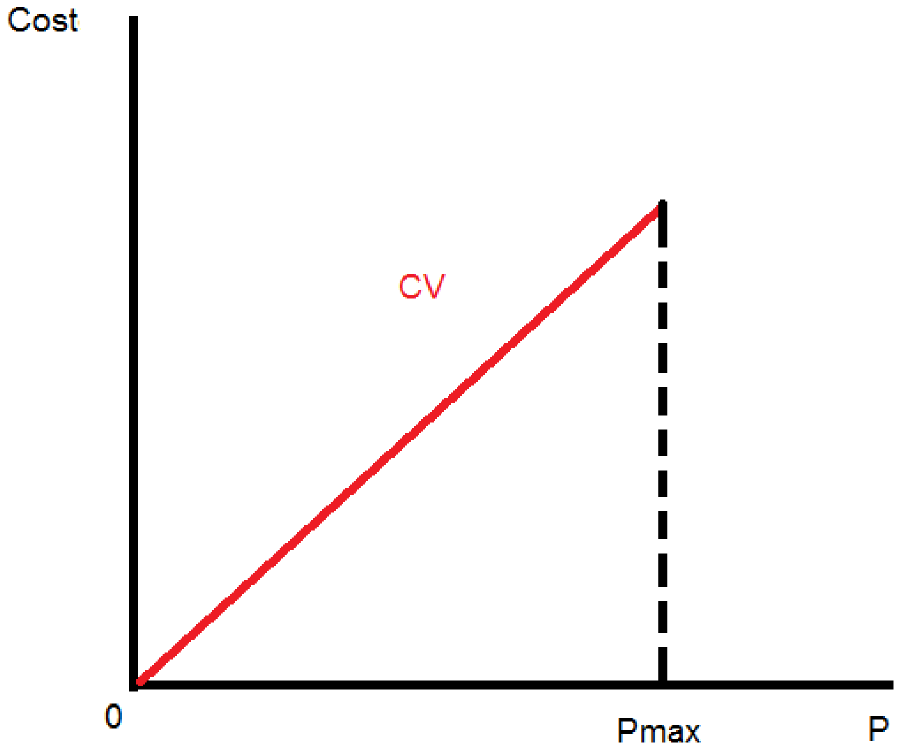


Fig. 6: Cost associated with the consumption of fuels of the Actor according to the dispatched power

$$Cost_i = P_i . cv_{inc}$$

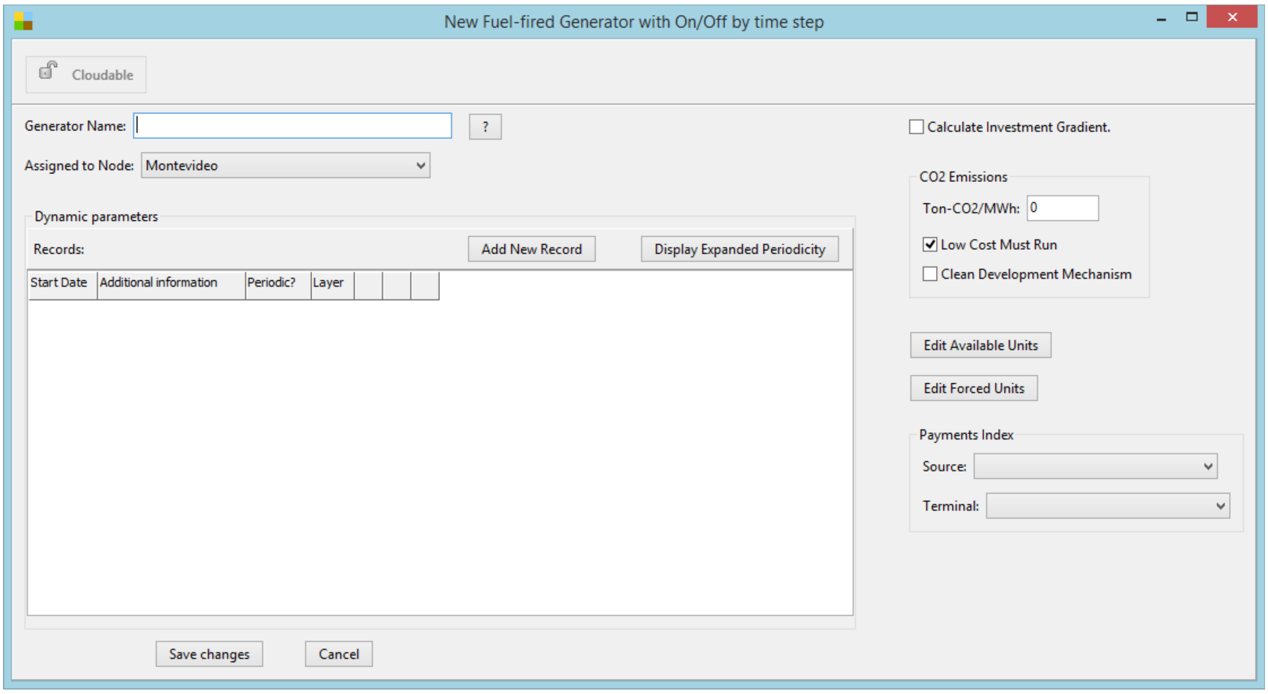
ec.5 Cost in USD/h associated with the fuel consumption of the Actor in the post i

7.4. *Fuel-fired Generator with On/Off by Time Step.*

The Fuel-fired Generator with On/Off by Time Step is an Actor that belongs to the Fuel-fired Group. If this Generator is dispatched in a time-band it must be dispatched in all the time-bands of the time step.

7.4.a) Operation description.

The registration form of the Fuel-fired Generator with On/Off by Time Step is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

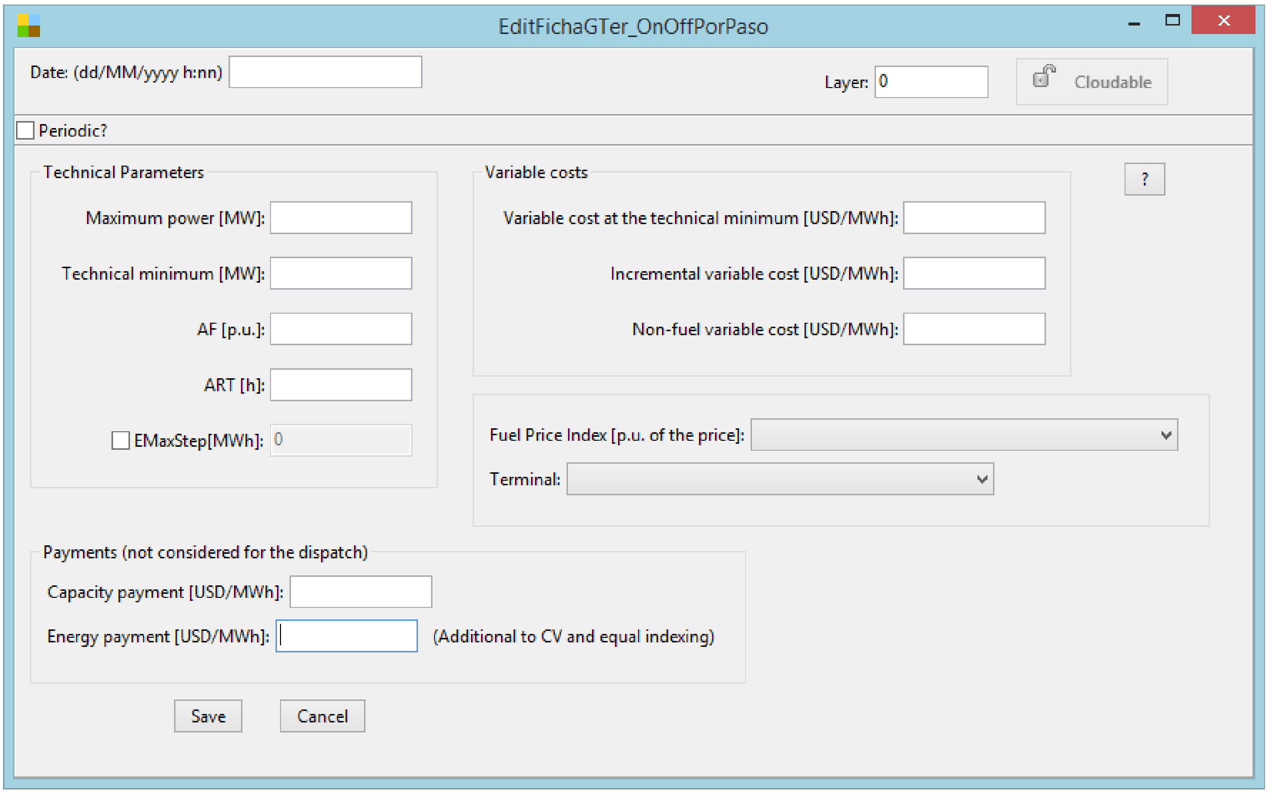
7.4.b) *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

7.4.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

In the "Technical Parameters" panel

- Maximum Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Technical Minimum: Minimum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- EmaxStep: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

In the “Variable Cost” panel

- Variable Cost at the Technical Minimum: It is the variable cost of production (cv_{inc}) in USD/MWh when the unit operates at the technical minimum. This cost can be indexed to the Fuel Price Index.

- Incremental variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.
- Non-fuel variable cost: It is the variable cost of production in USD/MWh that does not depend on the cost of the fuel used (e.g., operation and maintenance costs). This cost cannot be indexed to a price index.

7.4.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
c0	USD/h	No	No	Cost in USD/h per unit for operating at the technical minimum.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
PMeanDispatched	MW	No	No	Mean power dispatched in the time step.

7.4.e) State variables, Control and Restrictions.

The Actor does not add a State Variable to the system.

The Actor adds 2 Control Variable per time post i :

- A : Switching on the central by time step (ON/OFF = 1/0).
- p_i : Power dispatched above the technical minimum in MW for each time post i .

Constraints

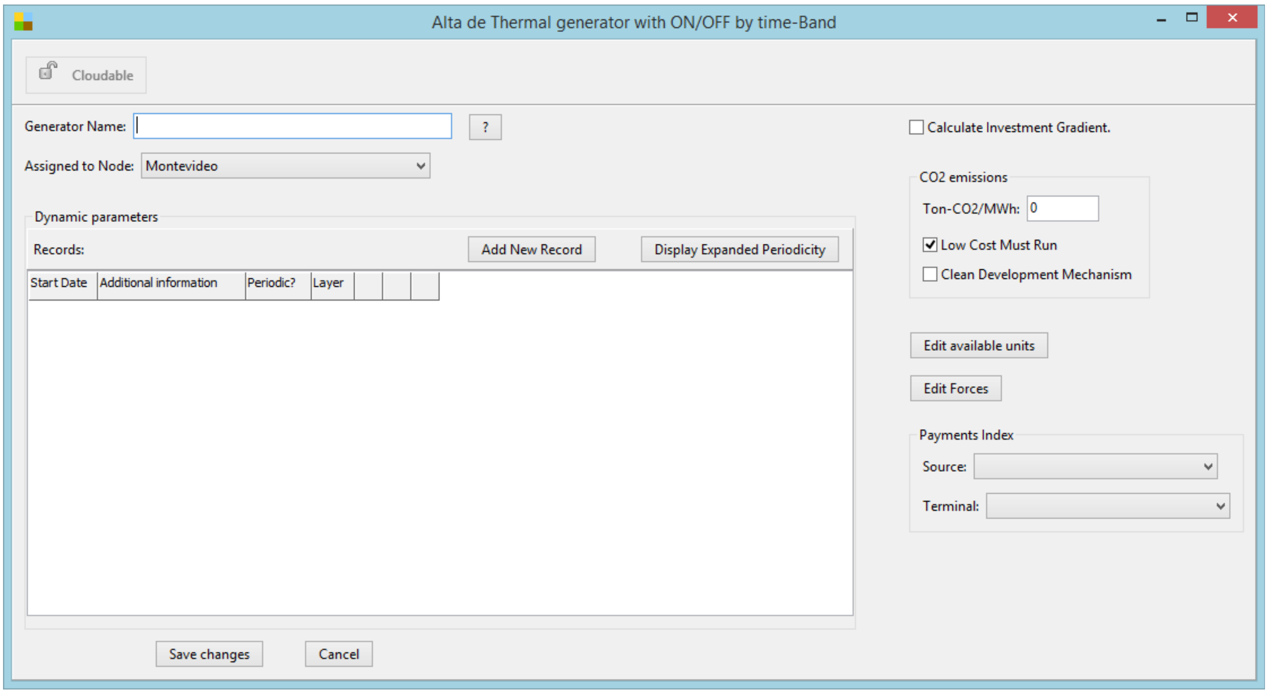
- $p_i \leq A.(Pmax - Pmin)$: Restriction imposed by the coupling variable for each time post i .

7.5. *Fuel-fired Generator with ON/OFF by Time-Band.*

The Fuel-fired Generator with Restricted On/Off by Time-Band is an Actor that belongs to the Fuel-fired Group.
Being a generator with ON/OFF by time-band, it can be dispatched in a time-band without the need to be dispatched in the entire time step.

7.5.a) Operation description.

The registration form of the Fuel-fired Generator with Restricted On/Off by Time-Band is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

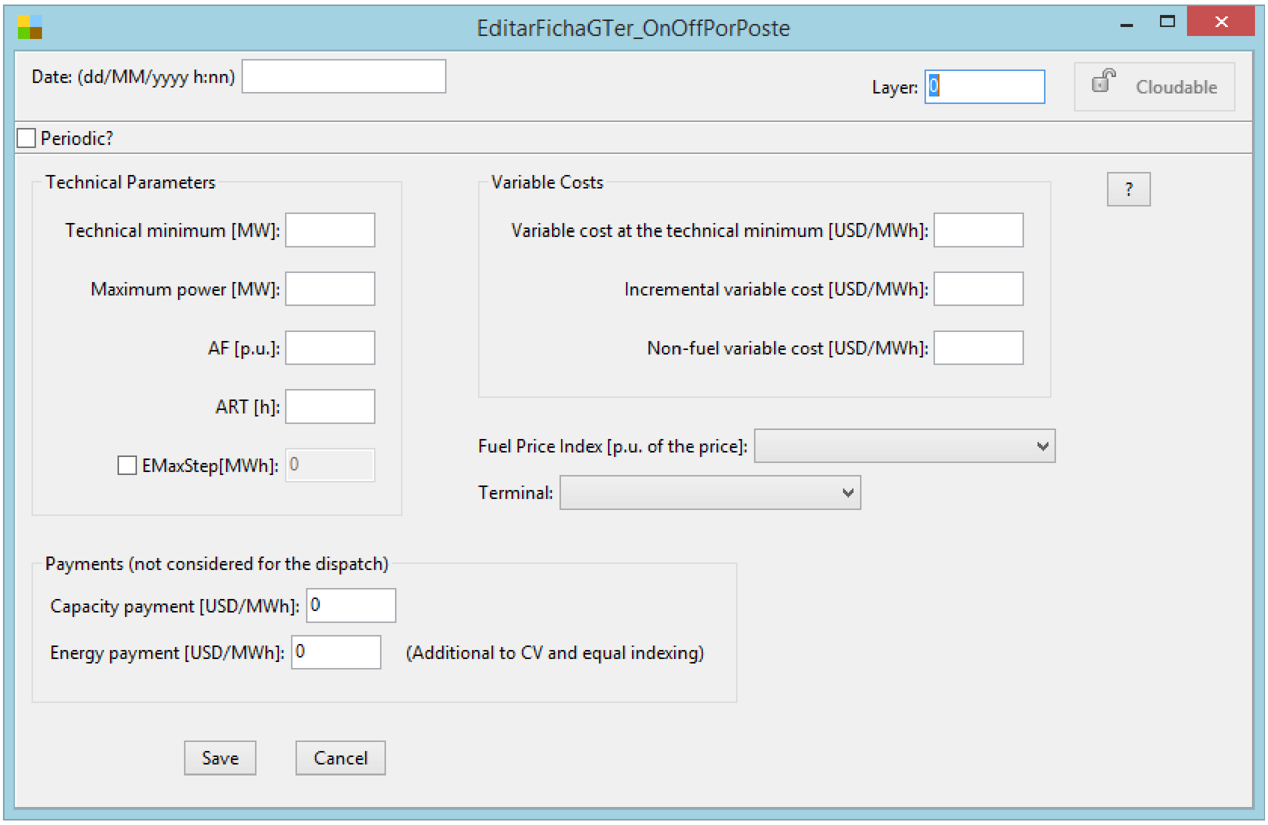
7.5.b) *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

7.5.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

In the "Technical Parameters" panel

- Technical Minimum: Minimum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Maximum Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- EmaxStep: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

In the “Variable Cost” panel

- Variable Cost at the Technical Minimum: It is the variable cost of production (cv_{inc}) in USD/MWh when the unit operates at the technical minimum. This cost can be indexed to the Fuel Price Index.

- Incremental variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.
- Non-fuel variable cost: It is the variable cost of production in USD/MWh that does not depend on the cost of the fuel used (e.g., operation and maintenance costs). This cost cannot be indexed to a price index.

7.5.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
c0	USD/h	No	No	Cost in USD/h per unit for operating at the technical minimum.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
CVe	USD/MWh	No	No	Payment for additional energy to the C.V., affected by the price index.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
PMeanDispatched	MW	No	No	Mean power dispatched in the time step.

7.5.e) State variables, Control and Restrictions.

The Actor does not add a State Variable to the system.

The Actor adds 2 Control Variable per time post i :

- A : Switching on the central by time step (ON/OFF = 1/0).
- p_i : Power dispatched above the technical minimum in MW for each time post i .

Constraints

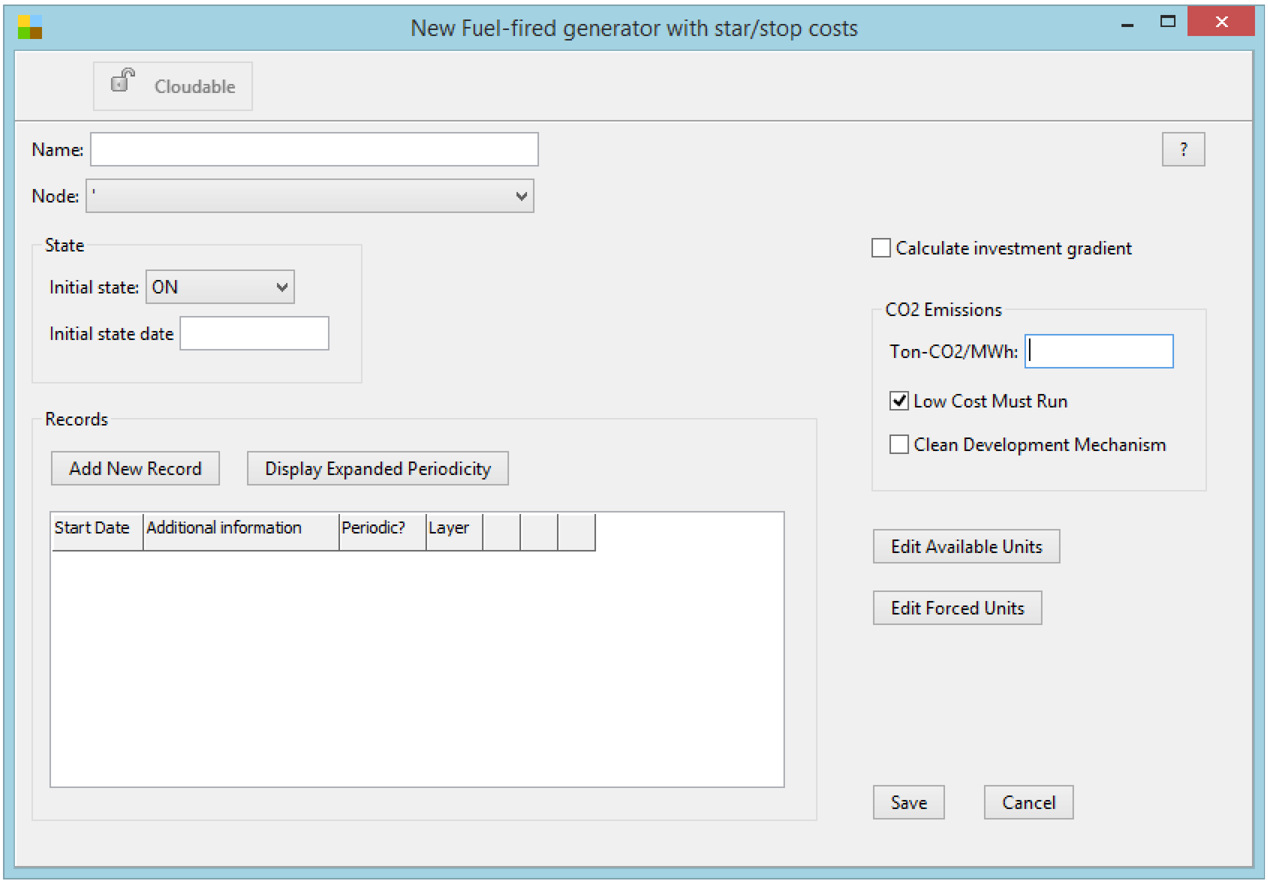
- $p_i \leq A.(Pmax - Pmin)$: Restriction imposed by the coupling variable for each time post i .

7.6. *Fuel-fired Generator with Start and Stop costs.*

The Fuel-fired Generator with Start and Stop Costs is an Actor that belongs to the Fuel-fired Group. The Actor allows you to specify a start and/or stop cost and temporary restrictions for these states.

7.6.a) Operation description.

The registration form of the Fuel-fired Generator with Start and Stop Costs is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

7.6.b) *Static parameters.*

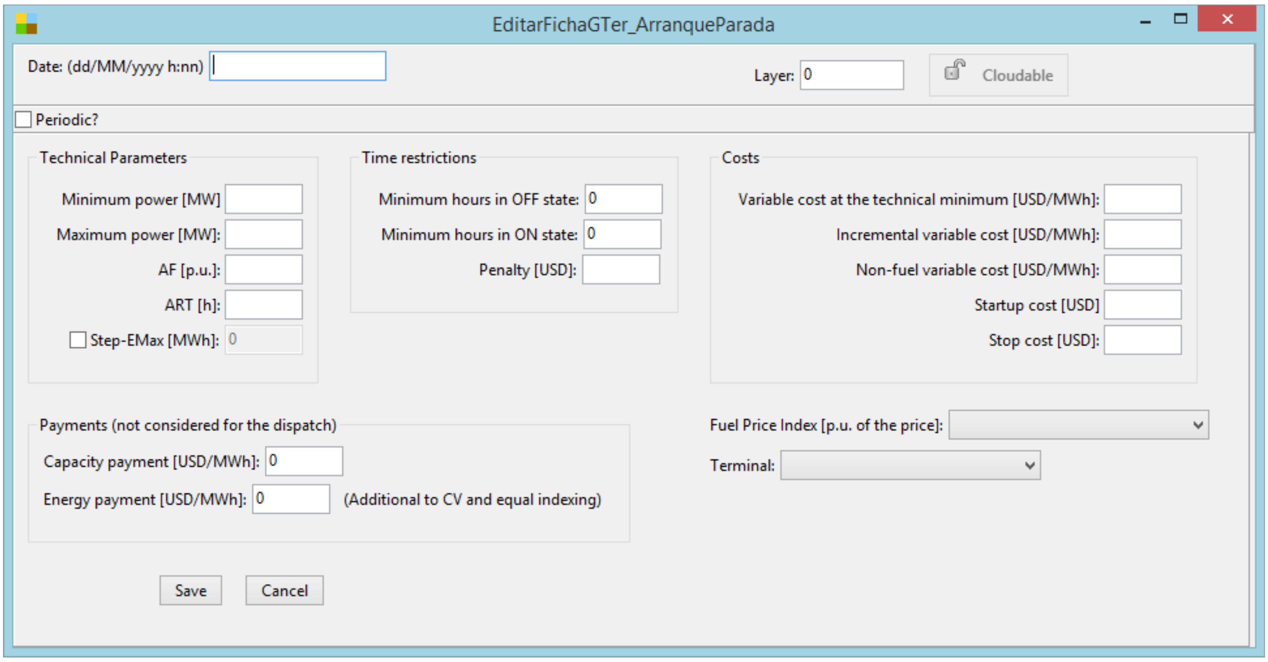
The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor and the initial state of the Actor at the beginning of the simulation.

In "Initial state" you must specify the state in which the generator is at the beginning of the simulation and the date from which it is in that state, in the "Initial state date" window.

7.6.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

In the "Technical Parameters" panel

- Minimum Power: Minimum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Maximum Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.

- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Step-Emax: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

In the "Time Restrictions" panel

- Minimum hours in OFF state: Number of hours that the Actor must remain in OFF state when it goes out of service.
- Minimum hours in ON state: Number of hours that the Actor must remain in ON state when dispatched.
- Penalty: Penalty for interrupting either of these two states before the specified time.

In the "Cost" panel

- Variable Cost at Minimum Power: It is the variable cost of production (cv_{inc}) in USD/MWh when the unit operates at the technical minimum. This cost can be indexed to the Fuel Price Index.

- Incremental variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.
- Non-fuel variable cost: It is the variable cost of production in USD/MWh that does not depend on the cost of the fuel used (e.g., operation and maintenance costs). This cost cannot be indexed to a price index.
- Start cost: The cost in USD that is incurred when the generator is put into operation (eg when starting and heating a steam boiler)
- Stop cost: It is the cost in USD that is incurred when the plant is turned off.

7.6.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
CVe	USD/MWh	No	No	Payment for additional energy to the C.V., affected by the price index.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time post.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
PMeanDispatched	MW	No	No	Mean power dispatched in the time step.
dCF	USD	No	Yes	Future cost gradient by state transition
c0	USD/h	No	No	Costo en USD/h por máquina por estar operando en el mínimo técnico

7.6.e) State variables, Control and Restrictions.

To take into account the start and stop costs of a fuel-fired generator, the state of the units must be considered as an additional state variable of the Future Cost function of the system. When this generator is created, it must be specified its initial state (ON/OFF) and the date since it is in that state.

The Actor add 1 State Variable to the system:

- Initial state of the units at the beginning of the time step (A = ON/OFF = 1/0)

The Actor adds 2 Control Variables:

- A : Switching on the units by time step (ON/OFF = 1/0)
- p_i : Power dispatched above the technical minimum in MW for each time post i .

Constraints:

- $p_i \leq A.(Pmáx - Pmín)$: Restriction imposed by the coupling variable for each time post i .

Temporary restrictions are possible time restrictions on the operation of the Actor. The restrictions that can be specified are Minimum hours in OFF state and Minimum hours in ON state. This implies that once the generator goes out of service, it must remain in that state the specified number of hours, and similarly if it is operating, it must continue in operation the specified number of hours. However, it is possible to pay a penalty to interrupt any of these two states before the specified time.

It is important to highlight that temporary restrictions do not apply during Optimization. They are applicable only during simulation.

Cost:

Be $CF(\{x, A\}, k)$ the Future Cost function at the end of the time step.

Where $\{x, A\}$ is the state variable of the system and in which the state of the rest of the system x has been differentiated from the state of the units represented by the Boolean variable A .

If at the beginning of the time step $A=0$ (the machine is turned off), the operation options during the time step are: DO NOT TURN ON (at the end of the time step $A=0$) or TURN ON, which means that $A=1$.

The cost associated with the fuel consumption of the plant when at the beginning of the time step it is turned off is calculated according to ec.6.

$$cost = \left(\sum_{i=1}^{NPosts} cv \, . \, p_i \, . \, DurPost_i \right) + cv_{PMin} \, . \, PMin \, . \, A \, . \, DurStep + cStart \, . \, A + \left(CF(\{x, 1\}, k) - CF(\{x, 0\}, k) \right) . \, A$$

ec.6 Cost in USD associated with fuel consumption per time step when the plant is

OFF.

Where:

p_i : Power dispatched above the technical minimum in MW for each time post i .

cv : Variable fuel cost above the technical minimum.

cv_{PMin} : Variable cost in the technical minimum

$cStart$: Start cost.

$cStop$: Stop Cost.

The startup cost is multiplied by A : If $A=1$ the control panel is switched on and if $A=0$ the control panel remains off.

The term $(CF(\{x,1\},k) - CF(\{x,0\},k)).A$ reflects the difference in the Future Cost function that is caused by the switching in the state as it passes from $A=0$ to $A=1$.

If the generator is ON at the beginning of the time step, the cost associated with fuel consumption is calculated according to the ec.7.

$$cost=(\sum_{i=1}^{NPosts} cv.p_i.DurPost_i) + cv_{PMin}.PMin.A.DurStep + cStop.(1-A) + (CF(\{x,0\},k) - CF(\{x,1\},k)).(1-A)$$

ec.7 Cost in USD associated with fuel consumption per time step when the plant is ON.

If the control panel is ON and continues ON, the cost is zero and the cost of the step is reduced to ec.8.

$$cost=(\sum_{i=1}^{NPosts} cv.p_i.DurPost_i) + cv_{PMin}.PMin.A.DurStep$$

ec.8 Cost in USD associated with fuel consumption per time step when the plant is located and remains ON.

If it is decided to turn off the plant, the stop cost must be paid.

The term $(CF(\{x,0\},k) - CF(\{x,1\},k)).(1-A)$ reflects the difference in the Future Cost function that is caused by the change of state of the plant when going from $A=1$ to $A=0$.

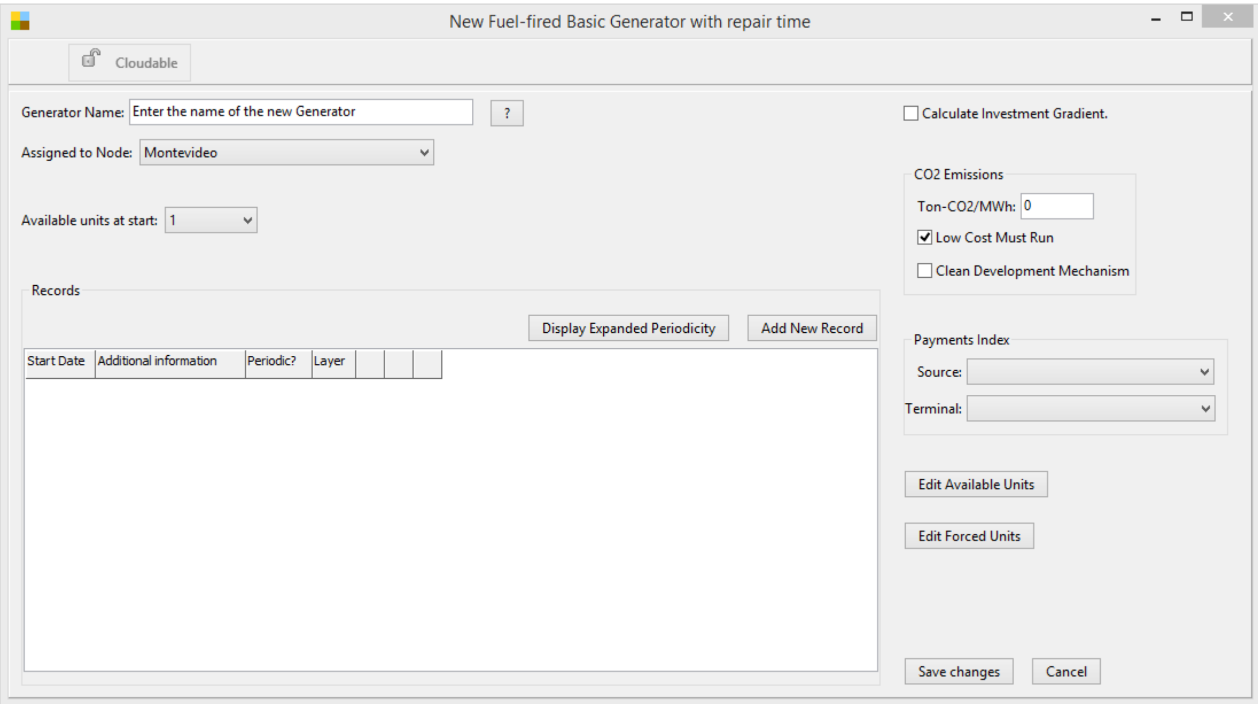
Depending on the size of the Actor with respect to the system as a whole and the start cost and stop cost compared to the cost of supply of the demand over a period of time, the terms that involve the difference of the Future Cost function will be more or less relevant and in some circumstances may be neglected.

7.7. *Fuel-fired Basic Generator with Repair Time.*

The Fuel-fired Basic Generator with Repair Time is an Actor that belongs to the Fuel-fired Group. The only difference that this type of generator presents with respect to the Fuel-fired Basic Generator is that in this case it must be specified if the generator is available at the beginning of the simulation.

7.7.a) Operation description.

The registration form of the Fuel-fired Basic Generator with Repair Time is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

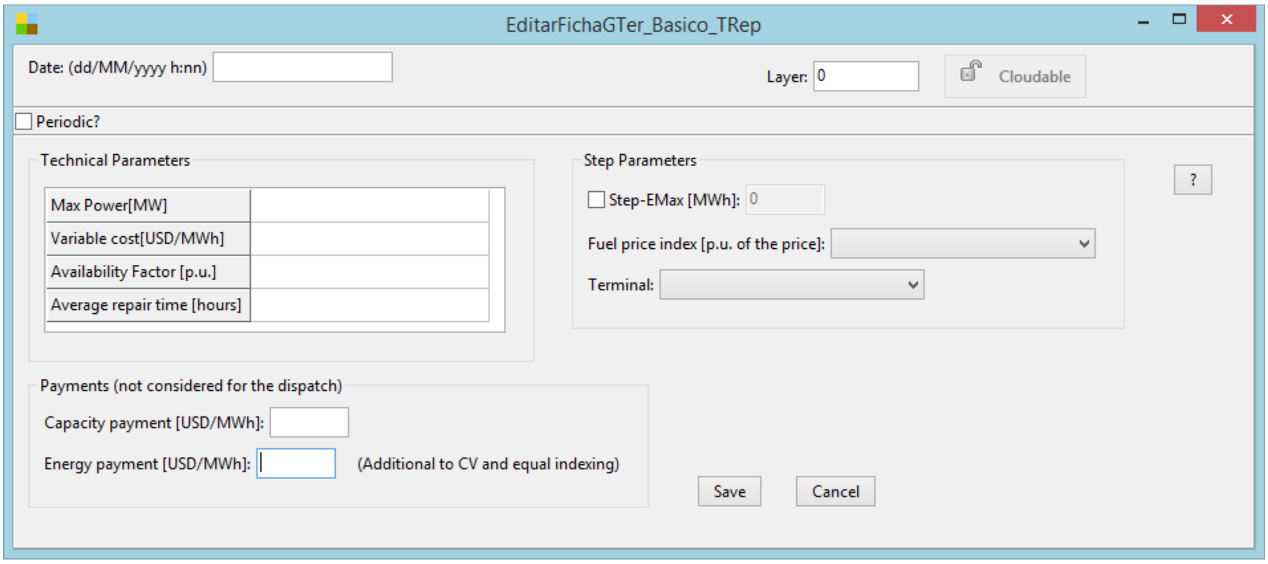
7.7.b) *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor. Additional it must be specified the number of available units at start of the simulation.

7.7.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- Max Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.
- Availability Factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- Average Repair Time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.

The "Step parameters" panel defines:

- Step-Emax: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

7.7.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
CVe	USD/MWh	No	No	Payment for additional energy to the C.V., affected by the price index.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time post.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
NForcedUnits	u	Yes	No	Number of forced units.
PMaxAvailable	MW	Yes	Yes	Maximun available power.

7.7.e) State variables, Control and Restrictions.

The Actor add 1 State Variable to the system.

- Number of available units in the beginning of the time step post. The Actor supports only single units power plants.

The Actor adds 1 Control Variable per time post i :

- P_i : Power output.

In Fig. 1 is plotted the cost $Cost_i$ in USD/h associated with the fuel consumption of the Actor according to the power dispatched in the time post i . The cost is defined by ec.1.

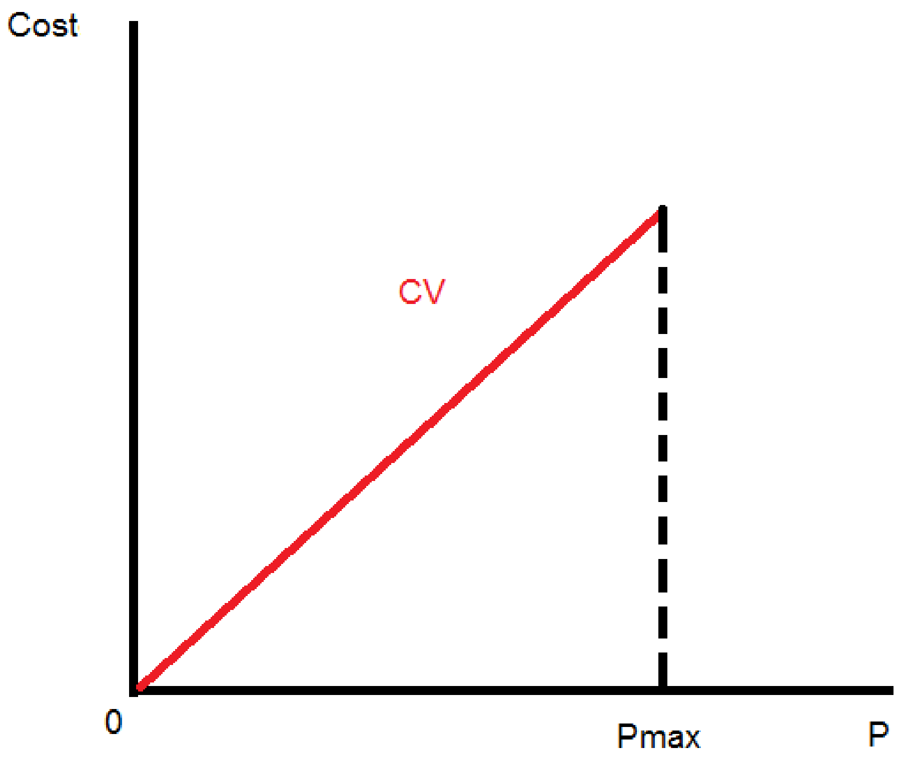


Fig. 7: Cost associated with the consumption of fuels of the Actor according to the dispatched power

$$Cost_i = P_i . cv$$

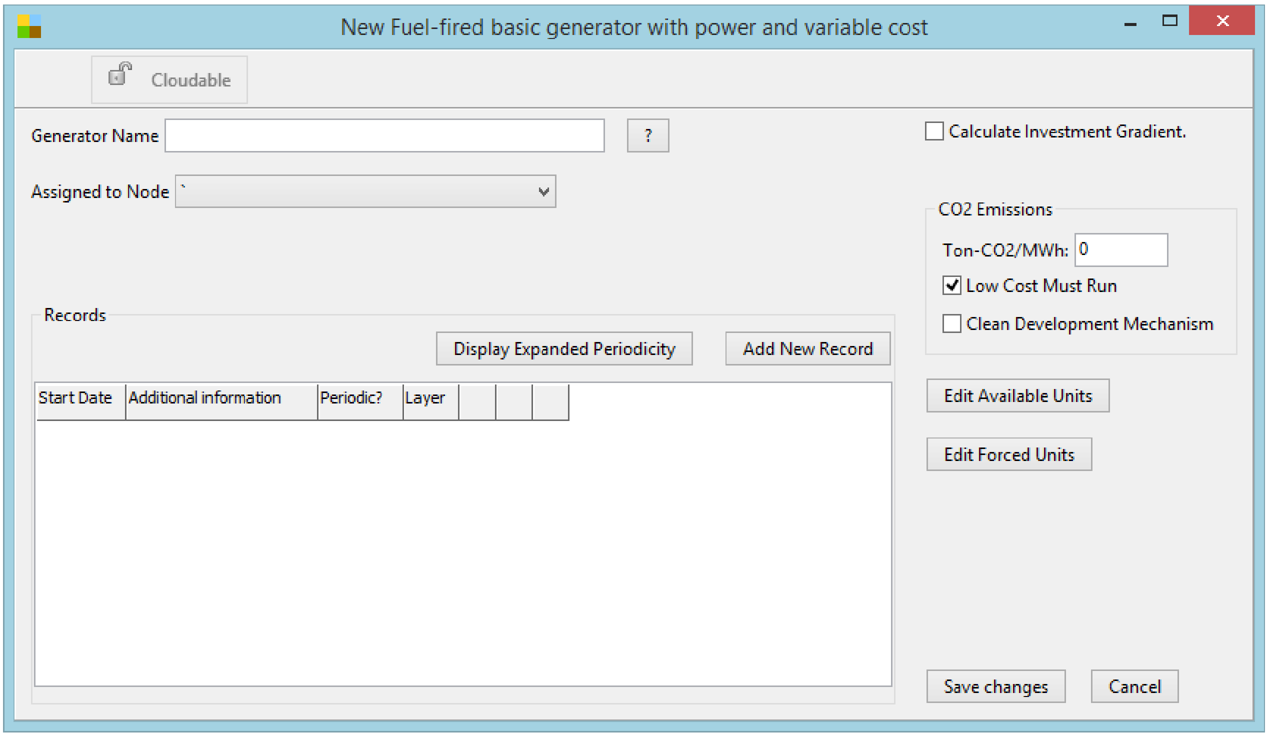
ec.9 Cost in USD/h associated with the fuel consumption of the Actor in the post i.

7.8. Fuel-fired Basic Generator with Power and Variable Cost.

The Fuel-fired Basic Generator with Power and Variable Cost is an Actor that belongs to the Fuel-fired Group. This type of generator is a simple generator, which can offer, in each of the time posts defined, a power value between 0 and a random value obtained from random sources at a price that it obtains from other random sources.

7.8.a) Operation description.

The registration form of the Fuel-fired Basic Generator with Power and Variable Cost is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

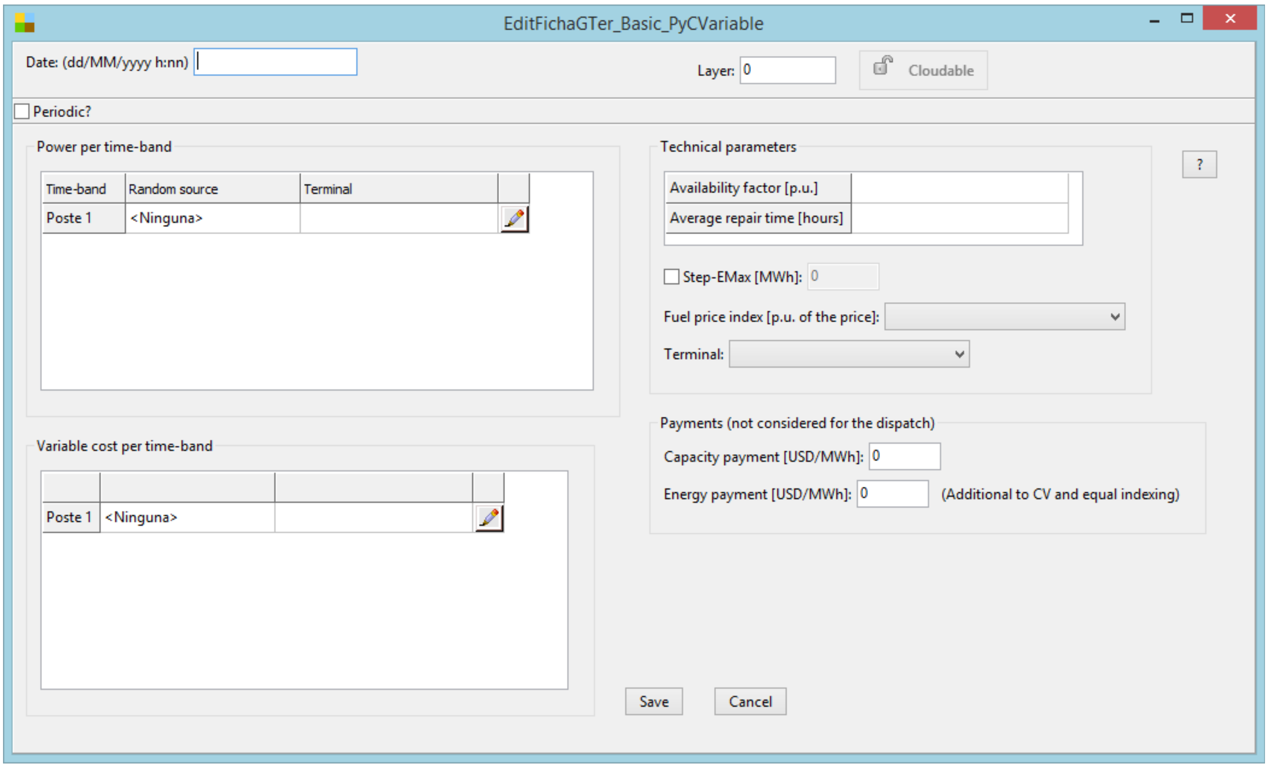
7.8.b) ***Static parameters.***

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

7.8.c) ***Dynamic parameters.***

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The “Powers per time post” panel defines:

Powers per time post: Maximum power in MW per time post that the Actor can generate and deliver to the Node of the Electricity Network. For each time post the power that can be offered will be between 0 and the value of the random source selected in that post.

For each time post, a random source with its associated terminal must be specified.

The "Variable Costs" panel defines:

- Variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.

The other parameters to specify are:

- Pmax: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Step-Emax: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

7.8.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
CVe	USD/MWh	No	No	Payment for additional energy to the C.V., affected by the price index.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time post.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
NForcedUnits	u	Yes	No	Number of forced units.
PMaxAvailable	MW	Yes	Yes	Maximun available power.

7.8.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 1 Control Variable per time post i :

- P_i : Power output.

In Fig. 1 is plotted the cost $Cost_i$ in USD/h associated with the fuel consumption of the Actor according to the power dispatched in the time post i . The cost is defined by ec.1.

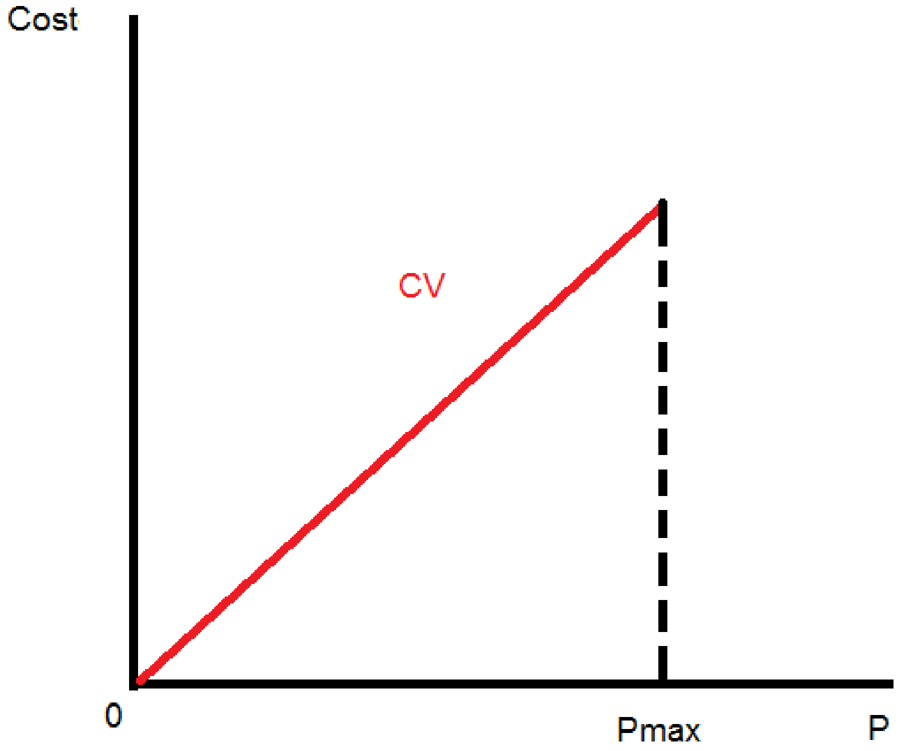


Fig. 8: Cost associated with the consumption of fuels of the Actor according to the dispatched power

$$Cost_i = P_i . cv$$

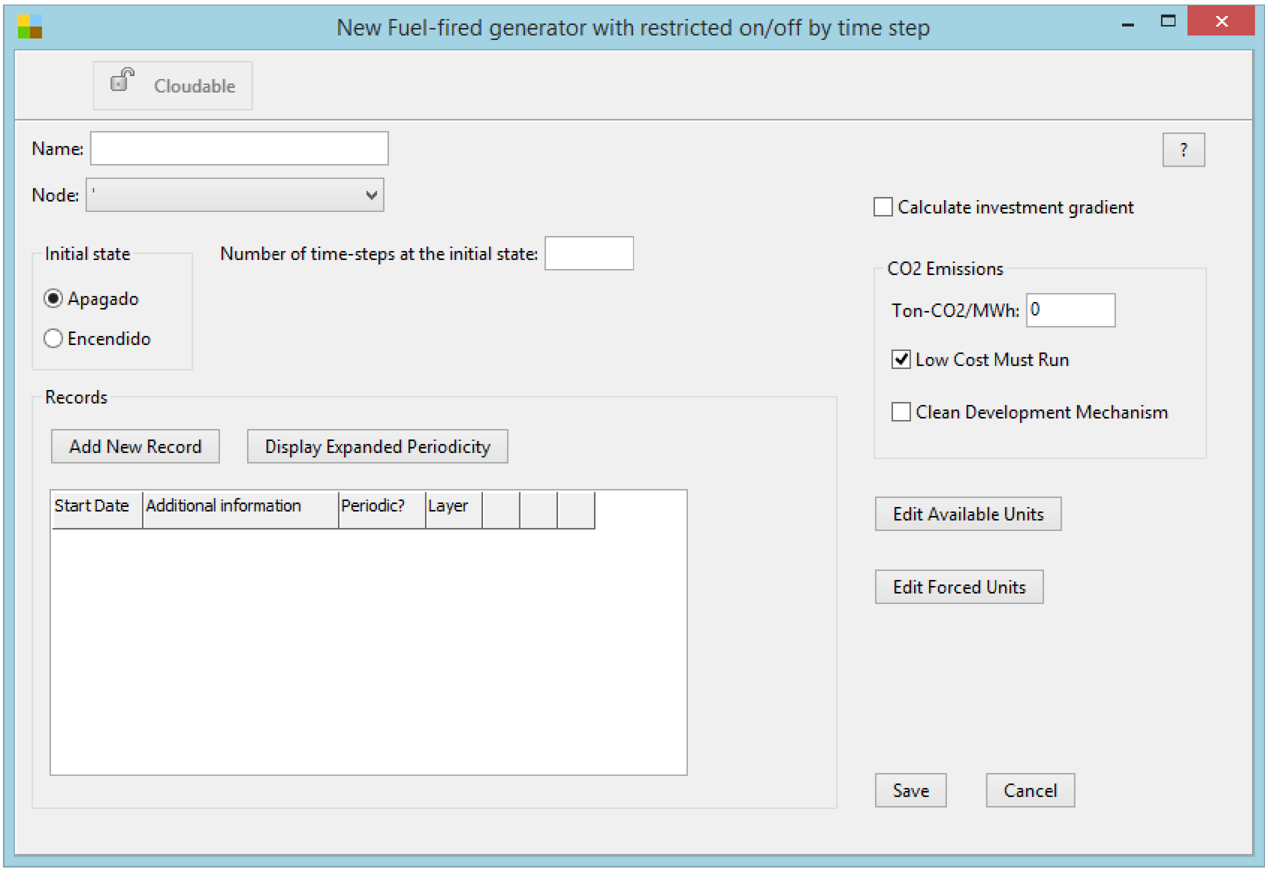
ec.10 Cost in USD/h associated with the fuel consumption of the Actor in the post i.

7.9. Fuel-fired Generator with Restricted On/Off by Time-Step.

The Fuel-fired Generator with Restricted On/Off by Time Step is an Actor that belongs to the Fuel-fired Group. This Actor allows you to define minimum time periods that must be respected for turning the units on and off.

7.9.a) Operation description.

The registration form of the Fuel-fired Generator with Restricted On/Off by Time Step is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

7.9.b) *Static parameters.*

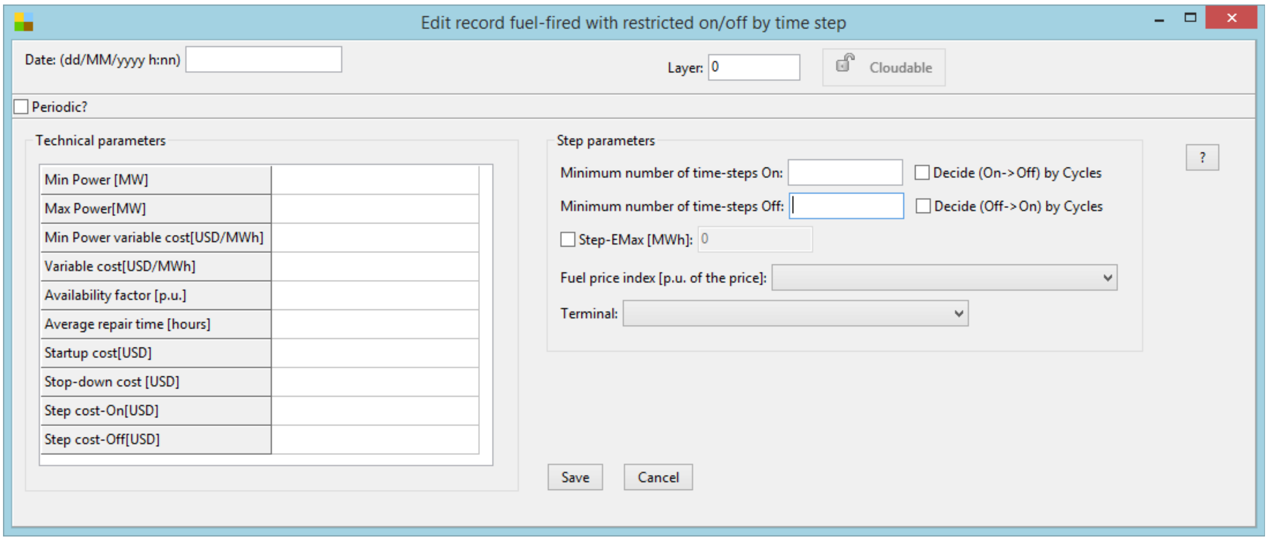
The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor and the initial state of the Actor at the beginning of the simulation.

In “Initial State” you must specify the state in which the generator is at the beginning of the simulation. Additionally, the minimum number of time steps that the generator must remain in each state and the costs incurred when the generator is in each state must be specified. The Generator supports a single unit or machine.

7.9.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- Maximum Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Minimum Power: Minimum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Variable Cost at Minimum Power: It is the variable cost of production (cv_{inc}) in USD/MWh when the unit operates at the technical minimum. This cost can be indexed to the Fuel Price Index.

- Variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.

- Availability Factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.

- Average Repair Time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Start cost: The cost in USD that is incurred when the generator is put into operation (eg when starting and heating a steam boiler)
- Stop cost: It is the cost in USD that is incurred when the plant is turned off.
- Cost Per Step ON/OFF: It is the cost in USD for each step in which the generator is on or off respectively, regardless of the power it may be delivering.

The parameters of the step are:

- Minimum Number of time steps On/Off: The minimum number of ON and Off steps of the generator. When the generator is turned on, at least a "Minimum Number of Steps On" must lapse before you can make the decision to turn it off. Similarly, once the control panel is turned off, at least a "Minimum Number of Steps Off" must lapse so that the control panel can be turned on again.
- Decide (On-> Off) by Cycles: If the box is checked, you can only decide to turn off the control panel when exactly the "Minimum Number of Steps On" or multiples of that amount have been fulfilled. If this box is not checked, the plant shutdown decisions can be taken at any time step after exceeding the "Minimum Number of Steps On".
- Decide (Off-> On) by Cycles: If the box is checked, the decision can only be made to turn on the control panel when exactly the "Minimum Number of Steps Off" or multiples of that amount have been fulfilled. If this box is not checked, the startup decisions of the control panel can be taken at any time after the "Minimum Number of Steps Off" has been exceeded.
- Step-Emax: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

7.9.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
CVe	USD/MWh	No	No	Variable cost of production affected by the price index.
CostAPP	USD	No	Yes	Fixed Cost for the units start and stop of the units, and for the step On/Off states.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time post.
NUnitsDispatchedInLastStep	u	No	No	Number of units dispatched in the previous time step.
c0	USD/h	No	No	Cost in USD/h per unit for operating at the technical minimum.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
PMeanDispatched	MW	No	No	Mean power dispatched in the time step.

7.9.e) State variables, Control and Restrictions.

The Actor add 1 State Variable to the system.

- $xOnOff$: Number of time steps that the machine has been on or off.

  If $xOnOff \leq 0$ then $-xOnOff+1$ is the number of time steps that the machine has been off.
  If $xOnOff > 0$ then $xOnOff$ is the number of time steps that the machine has been on.

The Actor adds 2 Control Variable per time post i :

- A : Switching on the central by time step (ON/OFF = 1/0).
- p_i : Power dispatched above the technical minimum in MW for each time post i .

Constraints

- $p_i \leq A.(Pmax - Pmin)$: Restriction imposed by the coupling variable for each time post i .

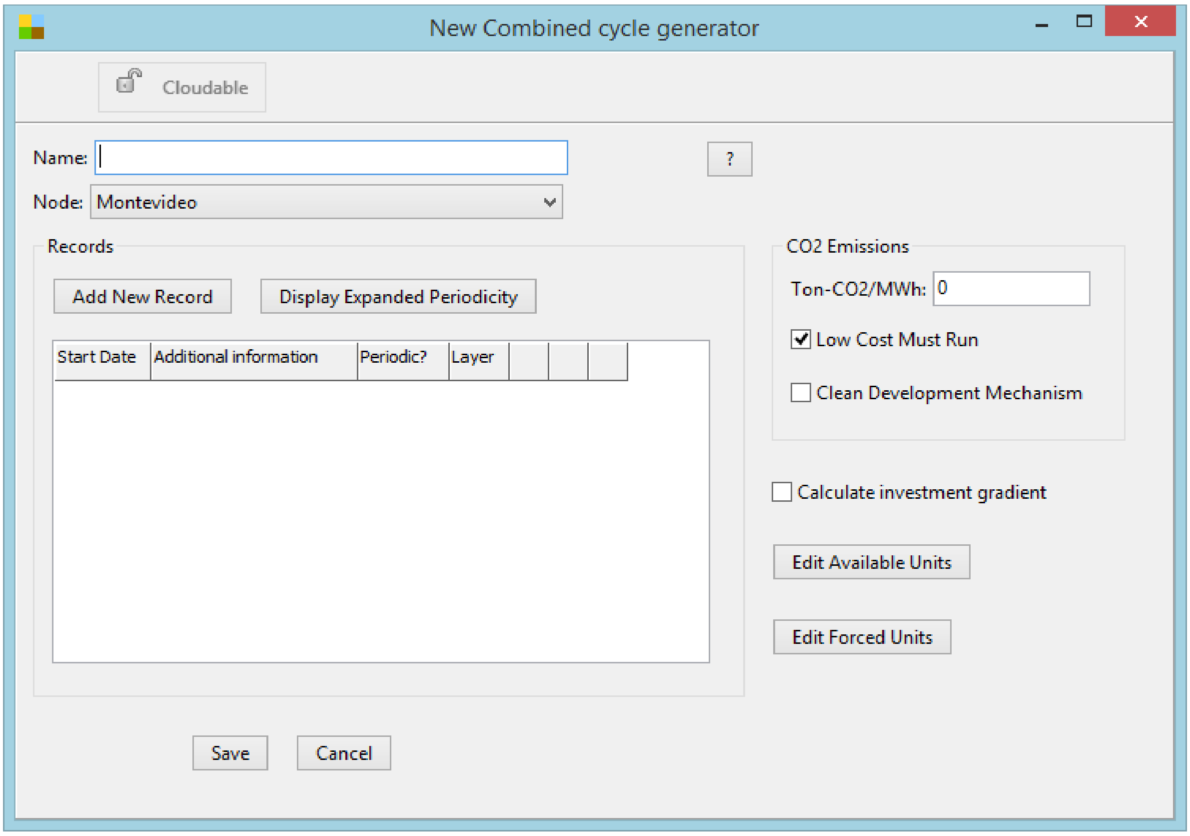
7.10. Combined Cycle Generator.

The Combined Cycle Generator is an Actor that belongs to the Fuel-fired Group. This Actor represents a power plant that has more than one turbine capable of generating electricity using different types of fuels, such as diesel or natural gas. This feature adds an important flexibility since it can work in different configurations and operation modes.

7.10.a) Operation description.

A combined cycle power plant can only operate with gas turbines, without operating the steam turbine, in which case we talk about open cycle operation. If the plant is operating with the gas turbines together with the steam turbine, it is said to be operating in a closed cycle. Normal operation is considered when the plant operates in a closed cycle, with all turbines above its technical minimum.

The registration form of the Combined Cycle Generator is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

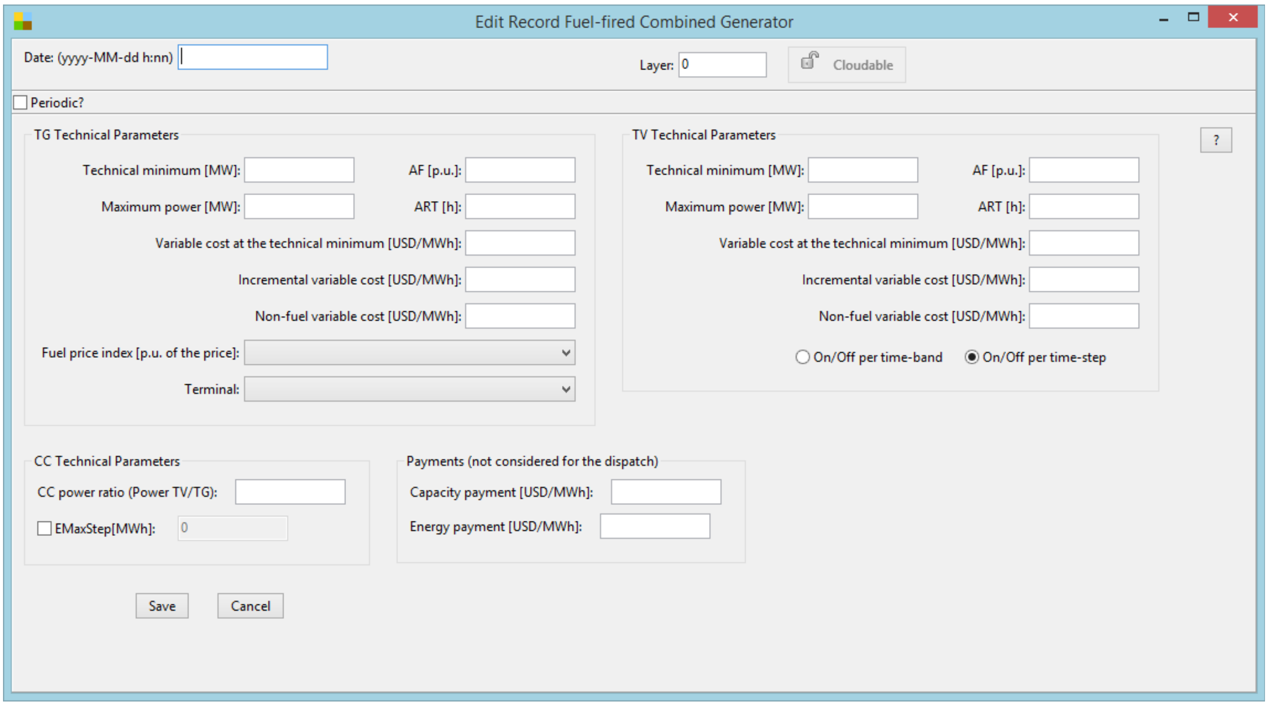
7.10.b) *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

7.10.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



In the panels "TG Technical parameters" and "TV Technical parameters" you must specify:

- Technical Minimum: Minimum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Maximum Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- Variable Cost at the Technical Minimum: It is the variable cost of production (cv_{inc}) in USD/MWh when the unit operates at the technical minimum. This cost can be indexed to the Fuel Price Index.

- Incremental variable cost: It is the variable cost of production (cv_{inc}) in USD/MWh for all levels of the energy generation of the Actor. This cost can be indexed to the Fuel Price Index.
- Non-fuel variable cost: It is the variable cost of production in USD/MWh that does not depend on the cost of the fuel used (e.g., operation and maintenance costs). This cost cannot be indexed to a price index.
- On/Off per time-band or On/Off per time-step: If “On/Off per time-step” is selected, the cycle is combined per time-step; the control panel generates equal or above the technical minimum during all hours of the time-step. If “On/Off per time-band” is selected, the cycle combination is performed independently for each time-band.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.

In the panel "CC Technical parameters” you must specify:

- CC Power Ratio: Parameter that represents the thermodynamic coupling between the TG and TV. The power generated by the TVs cannot exceed the product between the CC Power Ratio and the Power generated by the TG.
- Step-Emax: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

7.10.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NunitsDispatched TG/TV	u	Yes	Yes	Number of TG/TV dispatched units.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time-band.
NavailableUnits TG/TV	u	No	Yes	Number of TG/TV available units in the time-band.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
PMeanDispatched	MW	No	No	Mean power dispatched in the time-step.

7.10.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 4 Control Variables:

- A_{TGi} : Startup of the TG turbines (On/Off = 1/0) per time-band i .
- A_{TVi} : Startup of the TV turbines (On/Off = 1/0). It can be one variable per time-band or per time-step as specified in the dynamic parameters.
- β_{TGi} : Power dispatched by the TG above the technical minimum in MW for each time post i .
- β_{TVi} : Power dispatched by the TV above the technical minimum in MW for each time post i .

Cost:

In Fig. 9. the $Cost_i$ in USD/h associated with the fuel consumption P_i of the power plant is plotted according to the power dispatched in the time-band i . The cost is obtained from ec.11.

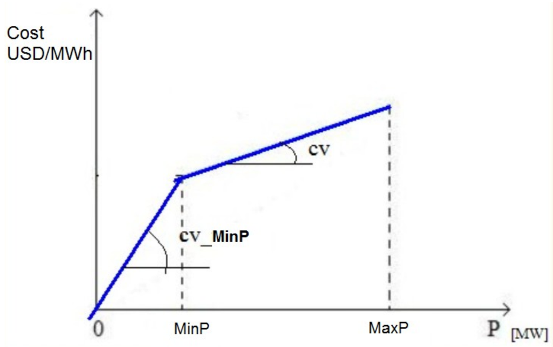


Fig. 9: Cost associated with the fuel consumption of the Actor according to the dispatched power.

$$Cost_i = cv_{MinP}.MinP + cv.(P_i - MinP)$$

ec.11 Cost in USD/h associated with the fuel consumption of the Actor in the time-band i .

Constraints:

Coupling between TG and TV units:

The power dispatched by the TV units cannot exceed the product between the power dispatched by the TG units and the CC Power Ratio according to ec.12.

$$P_{TV} \leq k . P_{TG}$$ ec.12 Coupling restriction.

8. Storable Biomass Generator.

The Storable Biomass Generator is an Actor that belongs to the Thermal Group. This Actor was created to model flexibility of energy sale contracts based on energy from afforestation, required by certain Energy Markets. This type of Actor implements Take or Pay (TOP) contracts in which the Market undertakes to buy an annual volume of energy or pay for that energy even if it has not taken it. As a counterpart, the Generator undertakes to deliver to the Market the energy stored when it is required, at a price set in advance.

8.1. Descripción del funcionamiento.

The power dispatch of the generator is of the type “all” or “nothing” (partial dispatches are not allowed).

The implementation of TOP contract is assumed a little different from the common and is through a simile with an Energy Reservoir.

If the volume of Annual Committed Energy is called ACE, an energy reservoir capable of storing ACE is assumed and an hourly “rain” ace = ACE / (365 * 24) is considered.

The volume of energy stored will be increased in each hour by eca and decreased by the generation of energy that is requested from the plant by the centralized dispatch and by the energy spillage when reaching the top of the reservoir.

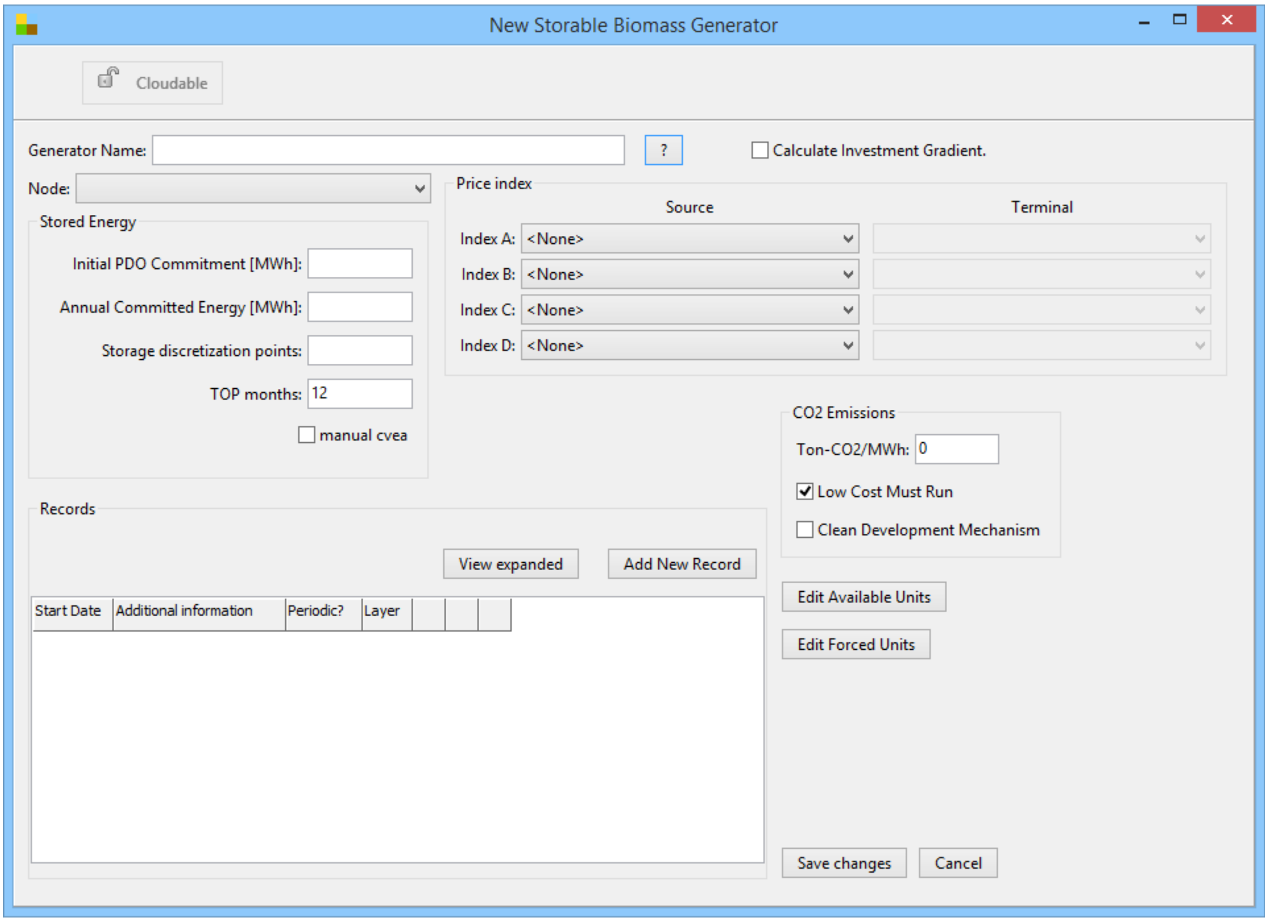
The price payed for energy consists of two separate components: a price for the committed energy PCE and another price PDE for the dispatched energy . The PCE is paid for the committed energy eca. The PDE price is paid for the volume of energy that is taken from the reservoir (either by energy dispatch or by spillage).

Being NP the Nominal Power of the plant (that the plant is capable of injecting to the system in a stable regime), the following condition must be met:

$$ACE \leq NP * 365 * 24 * fd \qquad \text{eq.(13)}$$

This restriction indicates that the annual energy commitment must be lower than the generating capacity of the plant with an availability factor of fd (considering scheduled and unscheduled maintenance).

The registration form of the Storable Biomass Generator is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

8.2. *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

The “Stored Energy” parameters to specify are:

- Initial PDO Commitment: Initial volume of energy committed in MWh. It can be used to simulate a CarryForward of the commitment or simply to reflect that the simulation corresponds to a time window in which the contract is already in operation.
- Annual Commited Energy: Annual commitment of energy in MWh. This commitment must be lower than the generating capacity of the plant multiplied by the availability factor (considering scheduled and unscheduled maintenance).
- Storage discretization points: Number of storage discretization points considered for the optimization of the operating policy. The minimum number of points must be 2 and correspond to the values of ZERO stored

energy and the maximum stored energy that is calculated as (Energy_Compromised_Annual / 12 * Months_TOP).

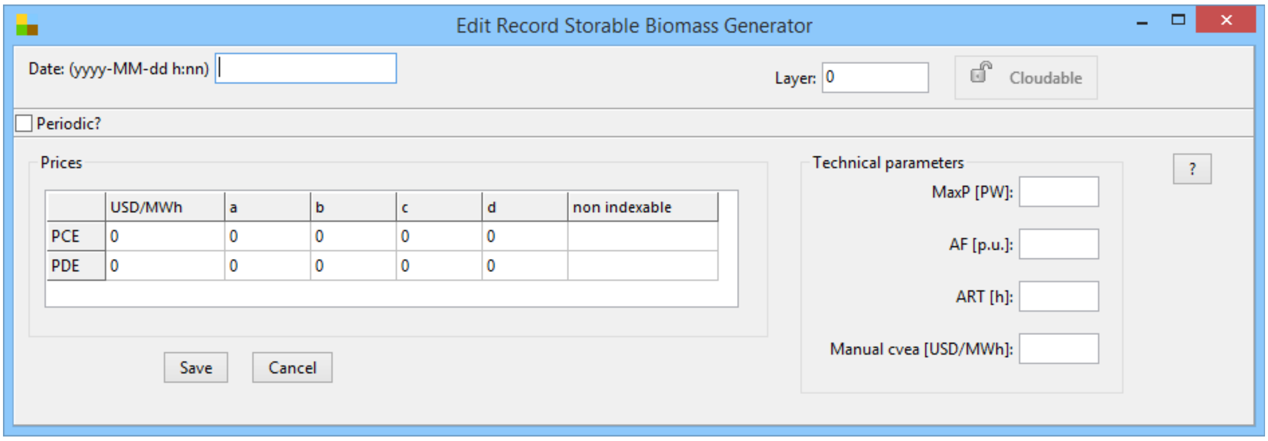
- Month of TOP: Number of months in which the committed energy may be required by the Market. If we figure that each energy commitment is stored with an expiration date, this date would be calculated as the sum of the commitment begining and the "TOP months".
- Manual cvea: Specifies if the value of stored energy is calculated from optimization or from a manually set value that must be specified in the ynamic parameters form.

The Sources and Terminals that will index the PEC (Committed Energy Price) and the PEE (Price for Energy Delivered) prices must be selected in the "Price Index" Panel.

8.3. Dynamic parameters.

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The “Prices” parameters to specify are:

- PCE: Price of the Committed Energy in USD/MWh. The generator receives this price for the compromised energy regardless if it is required by the Market.
- PDE: Price of the Delivered Energy in USD / MWh. The generator receives this price for the energy that is dispatched either because it is required for the Market or because is spilled or lost after the "TOP months" of commitment have passed.

- "a", "b", "c", "d": Factors in p.u. that mutiply the respective Sources (specified in the "Price Index" panel) to calculate the indexing of the PCE and PDE prices. The indexation of the price "P" is calculated as shown in the following equation.

$$idx_P = a_P . idx_a + b_P . idx_b + c_P . idx_c + (1 - a_P - b_P - c_P)$$

The "Technical Parameters" to specify are:

- MaxP: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Manual cvea: Value of the stored energy in USD/MWh. This value is used for the dispatch only if "Manual cvea" is checked in the "Stored Energy" panel.

8.4. *Published variables for SimRes.*

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
X_EA	MWh	No	No	Stored energy.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
SpilledEnergy_TOP	MWh	No	No	Spilled Energy.
DispatchedEnergy_DOP	MWh	No	No	Dispatched energy.
cvea	USD/MWh	No	No	Value of the Stored Energy.
Payments_TOP	USD	No	No	Payments received by the Actor for the commited energy.

8.5. State variables, Control and Restrictions.

The Actor add one State Variable to the system:

- X_{EA} : Stored energy at the beginning of the step.

The Actor adds 2 Control Variable:

- A : Switching on the central by time step (ON/OFF = 1/0).
- VE : Energy spillment of the central by time step in MWh.

The Actor adds the following constraints to the optimization problem:

- Node power restriction.
- Balance restriction of energy: $XEA_s = XEA + ecs - A.eds - VE$. Being ecs and eds the commited and dispatched energy in the time step respectivey, and XEA_s and XEA the stored energy at the end and at the beginning of the time step respectively.

The Direct Cost incurred by the Actor is calculated as shown in the following equation:

$$DirectCost = ecs.PCE + A.eds.PDE$$

The Future Cost incurred by the Actor is calculated as the variation of the global Future Cost $CF(..,X_{EA},...)$ as a consecuence of the variation of the Variable State of the Actor in the time step:

$$FutureCost = dCF/dXEA.(XEA_s - XEA)$$

8.6. Combined Cycle Power Plant Model for hourly time step simulations.

Proyecto: SimSEE
Archivo: Modelo de Central de Ciclo Combinado horario en la plataforma SimSEE
Autor: Vanina Camacho
Fecha: 27/12/2019

Introduction

The hourly combined cycle power plant model in SimSEE allows taking into account the time needed to close the cycle, considering the purge times of the boilers and the charging time of the steam turbine.

In this document we will refer to aeroderivative turbines that can burn diesel or natural gas such as TG and steam turbines such as TV. Combining the cycle means using the hot gases, combustion outlet in the TGs, to heat steam which is then expanded in the TVs. The complete plant will be referred to as CC (Combined Cycle).

In this model, it is assumed that each TG has an associated boiler, which can be coupled or not to generate steam. The set of coupled boilers, generate steam at the same pressure that feeds the set of TVs.

Operating modes.

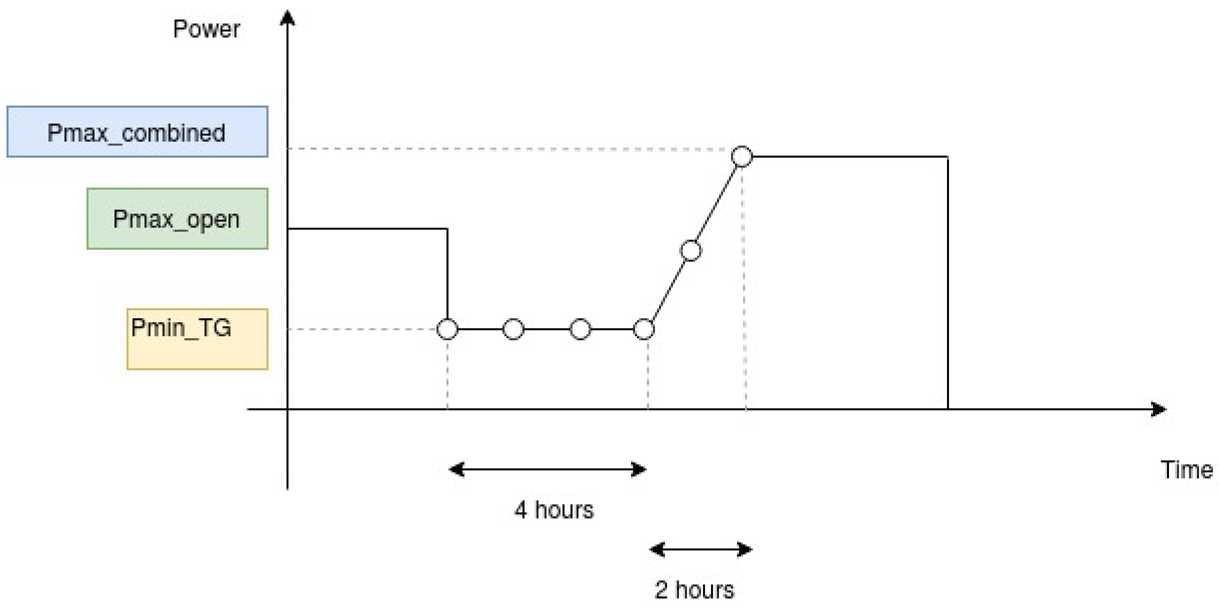
Each TG + Boiler group can be in one of the following modes of operation:

1. No turbine running.
2. TG (s) running alone (open cycle).
3. TG (s) + Boiler (combined cycle).

Example, if combining the cycle takes 6 hours (4 hours of purging and 2 for the TV to reach full):

To go from mode 2 to 3, it is necessary to lower the power of the TG to a minimum and wait 4 hours (purge time), after this time you have to slowly increase the power dispatched from the TG, and therefore the power of the TV, to reach the full it takes about 2 more hours (time to reach full). This is a total of 6 hours to go from 2 to 3. It takes the same to go from 1 to 3, with the exception that the TGs are turned on at minimum and it is not necessary to lower them.

A graph of the operation of the model going from mode 2 to 3 and then to 1 is shown in the following figure:


Power
Pmax_combined
Pmax_open
Pmin_TG
Time
4 hours
2 hours

Each TG or TV unit is modeled separately considering for each unit its own parameters.

Pmin	Minimum Power	(MW)
Pmax	Max power	(MW)
co	Variable cost at minimum power	(U$S/MWh)
cv	Incremental Variable cost	(U$S/MWh)
Disp	Random Availability Coefficient	(pu)
TMR	Average Repair Time	(hours)

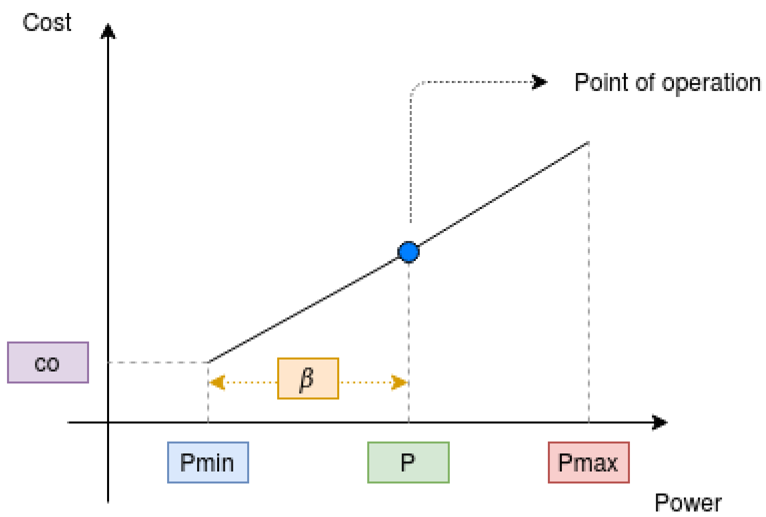
The parameters of the combined cycle are:

horasPurga	Time in which the TG are at a minimum to be able to combine.	(hours)
horasTVPleno	Time to be used to get the CC to be full.	(hours)
N° Discretizaciones del timer	Number of discretizations of the state variable for optimization. It must be the sum of the previous two.	-
horasEnfriarCaldera	Remaining number of hours for the boiler to cool, with this parameter the starting types are determined.	(hours)
N° Discretizaciones de la caldera	Number of discretizations of the state variable for optimization.	
k	TV/TG power ratio	(pu)
Costo por combinar	Cost of keeping combined the CC	USD

As a thermodynamic coupling between TVs and TGs, the power ratio defined as:

$$k = \frac{\text{Potencia TV}}{\text{Potencia TG}}$$

For each type of unit (TG or TV) the following model is considered:



To consider the non-convexity of the model, an integer variable A is used that indicates whether the control panel is on or off. If it is on it generates a power greater than or equal to $Pmin$.

If $A=0$ then $P=0$ and the cost is zero (The unit is out of service).

If $A=1$ then $P=Pmin+\beta$ (The unit is running).

With these definitions, the power injected by the Unit in the node will be:

$$P=(Pmin\times A)+\beta$$

Being fulfilled: $P\leq Pmax\times A$
Restriction that can be expressed as: $0\leq(Pmax-Pmin)\times A-\beta$

A Timer status variable is considered for each TG to represent the time elapsed after it is decided to combine the cycle. It can take values between 0 and $(horasPurga+horasTVPleno-1)$.

Depending on the values taken by the Timer, it is known in what state the starting process of the combined cycle is. With the following interpretation:

- **Timer = 0**, el ciclo esta abierto
- **Timer in [1, horasPurga)**, the cycle is combined, with the TG to the minimum, TV off. (Purge).
- **Timer in [horasPurga, (horasPurga + horasTVPleno))**, you start turning on the TV with the relationship $P_{TV}=k\,P_{TG}$
- **Timer = (horasPurga + horasTVPleno)** full combined cycle.

The dynamic constraint associated with the Timer state variable is:

$$-Xsi_{timer}+Ai_{acople}[Xi_{timer}+\Delta t]\geqslant 0$$

where Ai_{acople} is an integer control variable that indicates whether it was decided to close the cycle with TG_i (voucher 0 or 1) and Δt is the duration of the time step considered.

The control variables Ai_{TGSC} and βi_{TGSC} are used to represent the power of the TG i when the cycle is open. The variables Ai_{TGCC} and βi_{TGCC} represent the power of the TG_i when the cycle is closed.

As these variables represent the same TG but at different times, the SC and CC cannot be different from 0 at the same time, for that the restrictions are considered:

$$-Ai_{TGSC}+Ai_{acople}-1\geqslant 0$$

$$-Ai_{TGCC}+Ai_{acople}=0$$

In this way, when it is decided to close the cycle with TG i $Ai_{acople}=1$ and $Ai_{TGSC}=0$ (and therefore $\beta i_{TGSC}=0$). It also obliges that $Ai_{TGCC}=1$

With the open cycle $Ai_{acople}=0$ and $Ai_{acople}=0$

As for the power of the TV. The restriction varies depending on what part of the cycle you are in.

- While the timer is less than **horasPurga**, the TV remains off.
- When timer is between **horasPurga** and (**horasPurga + horasTVPleno**) the TGCC power is:
  $Pi_{TGCC}=A_{TGCCi}\,Pmin_{TG}+(pend_{TV}(Xi_{timer}-horasPurga)+PminTG)$
  $P_{TV}=k\sum Pi_{TGCC}$

  where $pend_{TV}=(PMaxTG-PMinTG)/(horasTVPleno)$ (It takes hours for TVPleno to move from PminTG to PmaxTG)

  The ratio of powers k=TV/TG is imposed with the following restriction:

  $$0=k\times\left[\left(Pmin_{TG}\times\sum_i A_{TGCC}\right)+\sum_i \beta_{TGCC}\right]-\left(Pmin_{TV}\times A_{TV}\right)+\beta_{TV}$$

  and βi_{TGCC} is regulated by imposing its maximum as:
  $$(pend_{TV}(Xi_{timer}-horasPurga)+PminTG)$$

- When Timer_i is (**horasPurga + horasTVPleno)**

  $$Pi_{TGCC}=Ai_{TGCC}\,Pmin_{TG}+\beta i_{TGCC}$$

To incorporate the types of warm or hot cold start, another state variable is added per boiler, called **estadoCaldera**, which indicates the number of hours left before the boiler cools.
The dynamic constraint associated with this variable is:

$$-Xsi_{caldera}+Ai_{acople}[pendSubidaCal\,\Delta t]+Xi_{caldera}-\Delta t\geqslant 0$$

where $pendSubidaCal\,\Delta t$ indicates the hours it takes to heat the boiler once it is decided to heat it (close the cycle).

The cost function associated to this central is:

$$FC=\sum_{i\in TGs}\left[co_{TG}\times\left(Pmin_{TG}\times A_{TGSC}\right)+cv_{TG}\times\beta_{TGSC}\right]\times\Delta t$$
$$+\sum_{i\in TGs}\left[co_{TG}\times\left(Pmin_{TG}\times A_{TGCC}\right)+cv_{TG}\times\beta_{TGCC}\right]\times\Delta t+\sum_{i\in TVs}\left[co_{TV}\times\left(Pmin_{TV}\times A_{TV}\right)+cv_{TV}\times\beta_{TV}\right]\times\Delta t$$

En resumen el modelo del SimSEE queda:

	Ai_{TGSC}	βi_{TGSC}	Ai_{TGCC}	βi_{TGCC}	A_{TV}	β_{TV}	Ai_{acople}	Xsi_{Tim}	Xsi_{C}	ti
nodo	$Pmin_{TG}$	1	$Pmin_{TG}$	1	$Pmin_{TV}$	1				
Dinamica-timeri							$X_{timer}+\Delta t$	-1		
Extincion TG SCi	$Pmax_{TG}-Pr$	-1								
Extincion TG CCi			$Pmax_{TG}-Pmin_{TC}$	-1						

Extincion TV					$Pmax_{TV} - Pm$	-1				
TvxTG			$k\ Pmin_{TG}$	k	$-Pmin_{TV}$	-1				
AcoplexTGSCi	-1						-1			1
AcoplexTGCCi			-1				1			
Dinamica-calderai							$pendSubida$		-1	$X_{caldera} -$
costo	$-co_{TG} \times \Delta t$	$-cv_{TG} \times \Delta t$	$-co_{TG} \times \Delta t$	$-cv_{TG} \times \Delta t$	$-co_{TV} \times \Delta t$	$-cv_{TV} \times$				

Restricciones de caja:

timer		A_{TGSC}	β_{TGSC}	A_{TGCC}	β_{TGCC}	A_{TV}	β_{TV}	A_{acople}	Xs_{Timer}
0-hPurga	min	0	0	0	0	0	0	0	0
	max	NTG	BMaxTG*NTG	NTG	0	0	0	1	5
Hpurga-hPurga + hPlenoTV	min	0	0	0	0	0	0	0	0
	max	NTG	BMaxTG*NTG	NTG	$(pend_{TV}(X_{timer} - horasI$	NTV	BMaxTV*NTV	1	5
>=hPurga + hPlenoTV	min	0	0	0	0	0	0	0	0
	max	NTG	BMaxTG*NTG	NTG	BMaxTG*NTG	NTV	BMaxTV*NTV	1	5

Observations

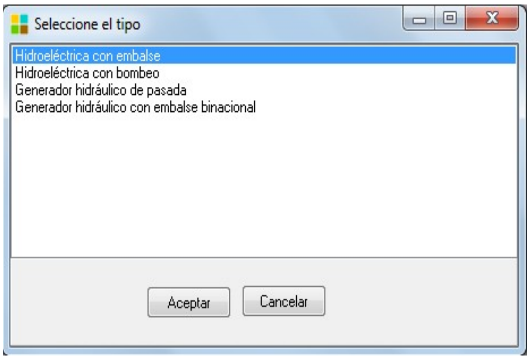
The model:

- Considers that the minimum technical when combined is the same as in open cycle
- Does not consider a cost to be coupled

9. Hydraulic Group

With the group of Actors of the Hydraulics tab, it is possible to model hydroelectric power plants in passing, with reservoir, with binational reservoir and with pumping. Whichever plant you wish to model, in all cases, it will be necessary to specify the name of the plant, the connection node, the number of available generation units (turbines) and the source of contributions with their respective terminal.

The different types of hydroelectric power plants available in SimSEE are shown in the figure below.



(THidroConEmbalse, THidroConBombeo, THidroDePasada, THidroConEmbalseBinacional).

9.1. Hydropower Plant with Reservoir.

The Hydropower plant with Reservoir is an Actor belonging to the Hidroelectrics Generators Group. The role of the Actor is to model hydropower plants with a reservoir for energy storage.

9.1.a) Operation description.

To define the Actor it is necessary to specify the parameters of the reservoir and their respective restrictions in the limits of the volume of the water stored. A schematic representation of the plant is presented in Fig.1.
Where:

1. V : It is the volume of water in the reservoir.
2. h : Is the height measured from the surface of the lake to the the turbine drain.
3. dV : Is the turbinated volume.
4. dE : Is the energy produced by the generation units.

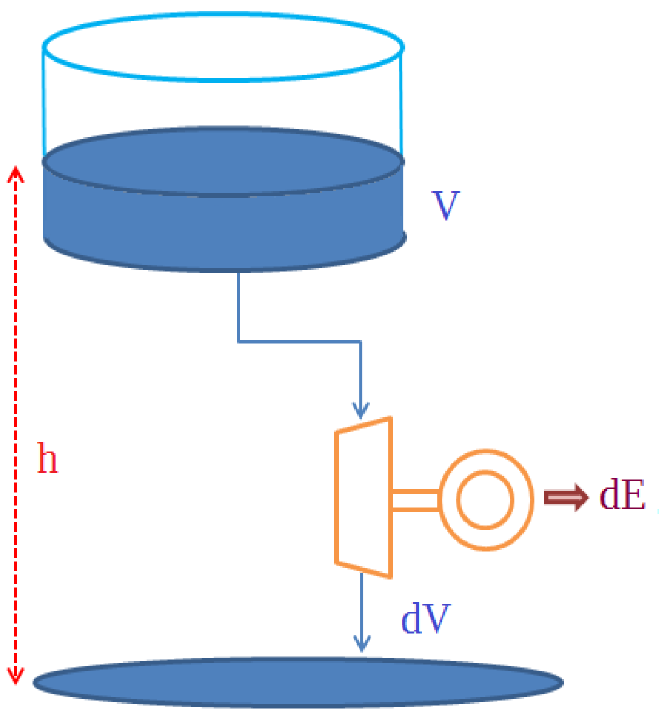


Fig. 10: Eschematic representation of the Hydropower Plant with Reservoir.

The volume V_{fin} at the end of the passage of time is calculated as the volume at the beginning V_{ini}, plus the volume that enters the lake due to the inflows of its own basin or by flows released in upriver power plants A, minus the turbinated volumes in each time post, minus the spillage volume Z minus evaporation losses and filtration of the reservoir R.

The final volume is calculated with ec.1:

$$V_{fin}=V_{ini}+A-\sum_{j=1}^{j=NPostes}\frac{P_j durpos_j}{ce}-Z-R$$

ec.1 Final volume of the reservoir.

Where the turbinated volume in the time post j is: $\frac{P_j durpos_j}{ce}$, where ce is the energy coefficient and $P_j durpos_j$ is the power delivered in the time post j multiplied by the duration of the post j.

The energy coefficient is determined by the function $dE=ce.dV$, where it represents the conversion factor between a turbinated volume dV and the energy generated and delivered by the plant to the electricity grid dE.

Considering the effective jump height h_{ej}, measured from the surface of the lake to the downstream river surface, we can write the energy coefficient as:

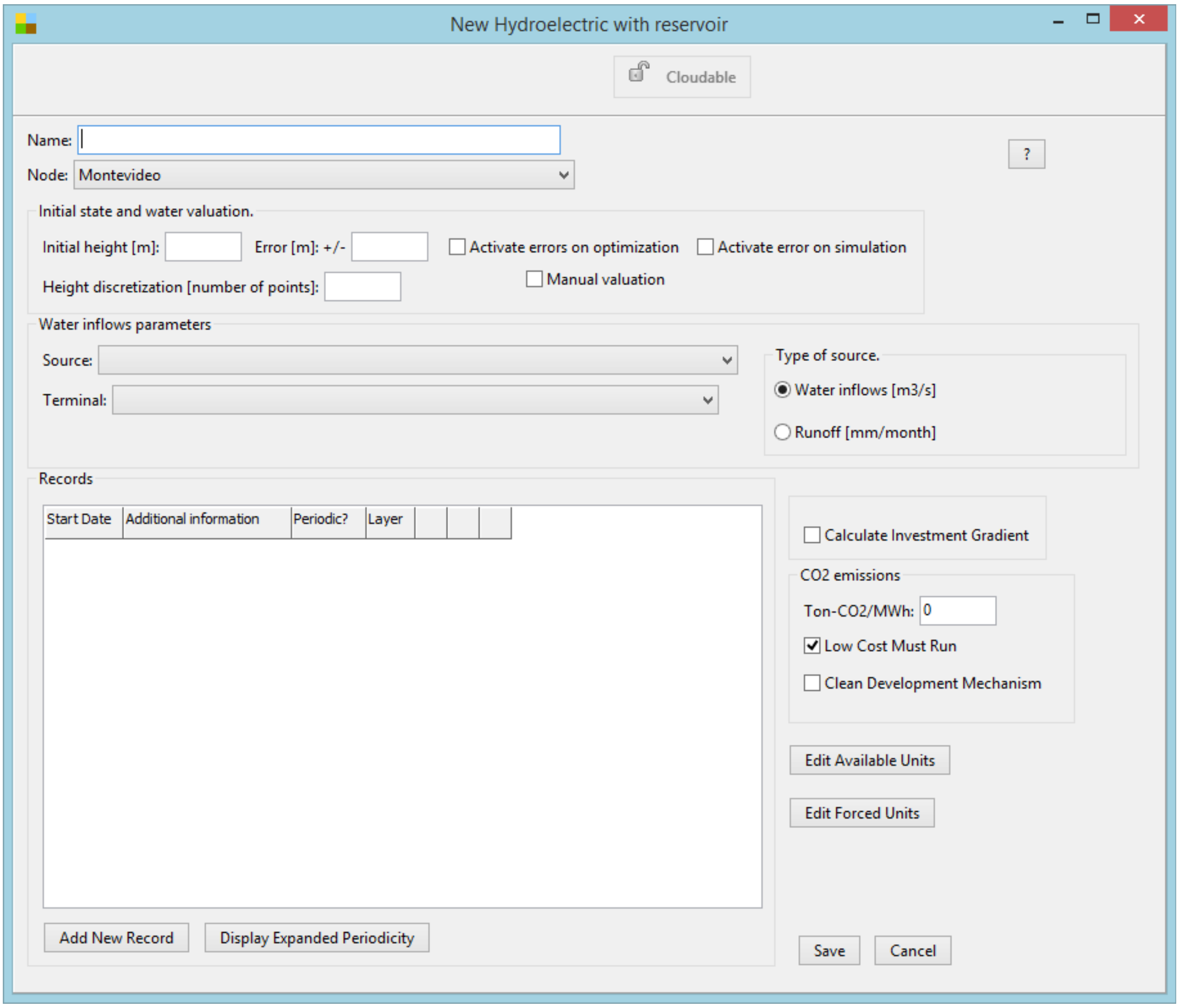
$$ce=\frac{h_{ej}\cdot\rho\cdot g\cdot\eta}{3600}[MWh/Hm^3]$$

Where:

- ρ Is the water density. ($1000 kg/m^3$)
- g Is the gravitational constant. ($9.8 m/s^2$)
- η It is the complex performance of the turbine and the electric generator.(p.u.)

As can be seen, the turbine volume equation as a function of the power generated by the plant is an approximation since the energy coefficient varies depending on the effective jump h_{ej}. The effective jump can vary depending on the level of the lake ($h_{ej}\leq h$ always holds) and by the variation of the level downstream, and the level downstream due to the turbinate flow itself. The energy coefficient also changes as the turbine efficiency varies, which is not constant for all water flows.

The registration form of the Hydropower Plant with Reservoir is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

9.1.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network that you want to associate the Actor with, and the inical state of the system, which is defined from the specification of the parameters found within the panel "Initial state and value of the water".

Within the above panel the following parameters must be specified:

- Initial height: It is the initial height of the lake in m.
- Error: It is the error that you want to add to the initial height. If it is desired that said error be considered in simulation time and / or in optimization time, the corresponding box must be checked.

- Height discretization: It is the number of points to discretize the reservoir.
- Manual valuation: Check the box if you want to manually carry out the water valuation. Once selected, the desired water value must be defined in each Record within the “Manual valuation” panel within the “Parameters 2” parameters tab.

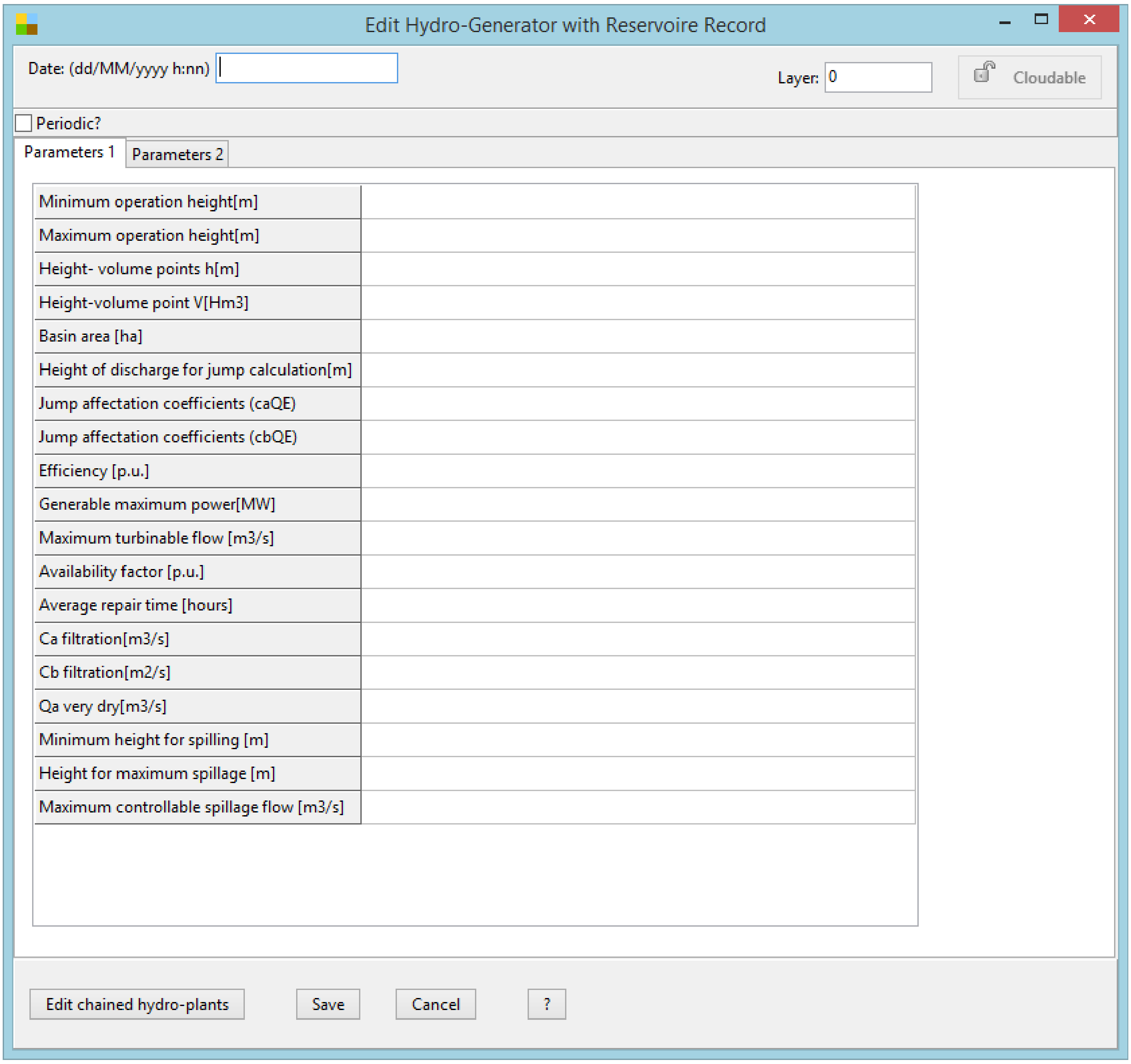
Within the panel "Water inflow parameters" a Source and Terminal can be specified, so that the Actor receives the information on the water inflow to the central basin. It must be specified if the source corresponds to inflow or filtration data within the basin.

9.1.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

For clarity, the registration panel of a Record is divided into two tabs called Parameters 1 and Parameters 2. Each tab of the registration panel of a Record is shown below:

9.1.c.i Parameters 1



The parameters to specify are:

- Minimum operation height: It is the minimum height in m of operation of the Reservoir.
- Maximum operation height: It is the maximum height in m of operation of the Reservoir.
- Height-volume points h: These are the height-volume points in m to determine the volume curve of the reservoir.
- Height-volume points V: These are the height-volume points in hm3 to determine the volume curve of the reservoir.
- Basin area: It is the surface area in ha. which occupies the basin of the reservoir.
- Height of discharge for jump calculation: It is the height in m. of downstream discharge.
- Jump affectation coefficients (caQ_E , cbQ_E): These are coefficients used to model the reduction of the effective jump due to the released flow. This reduction affects the calculation of the energy coefficient (Ce). The effective jump is calculated with ec.2.

$$dh(Q_{released}) = caQ_E \cdot Q_{released} + cbQ_E \cdot (Q_{released})^2$$

ec.2 Effective jump for released flow.

Where:

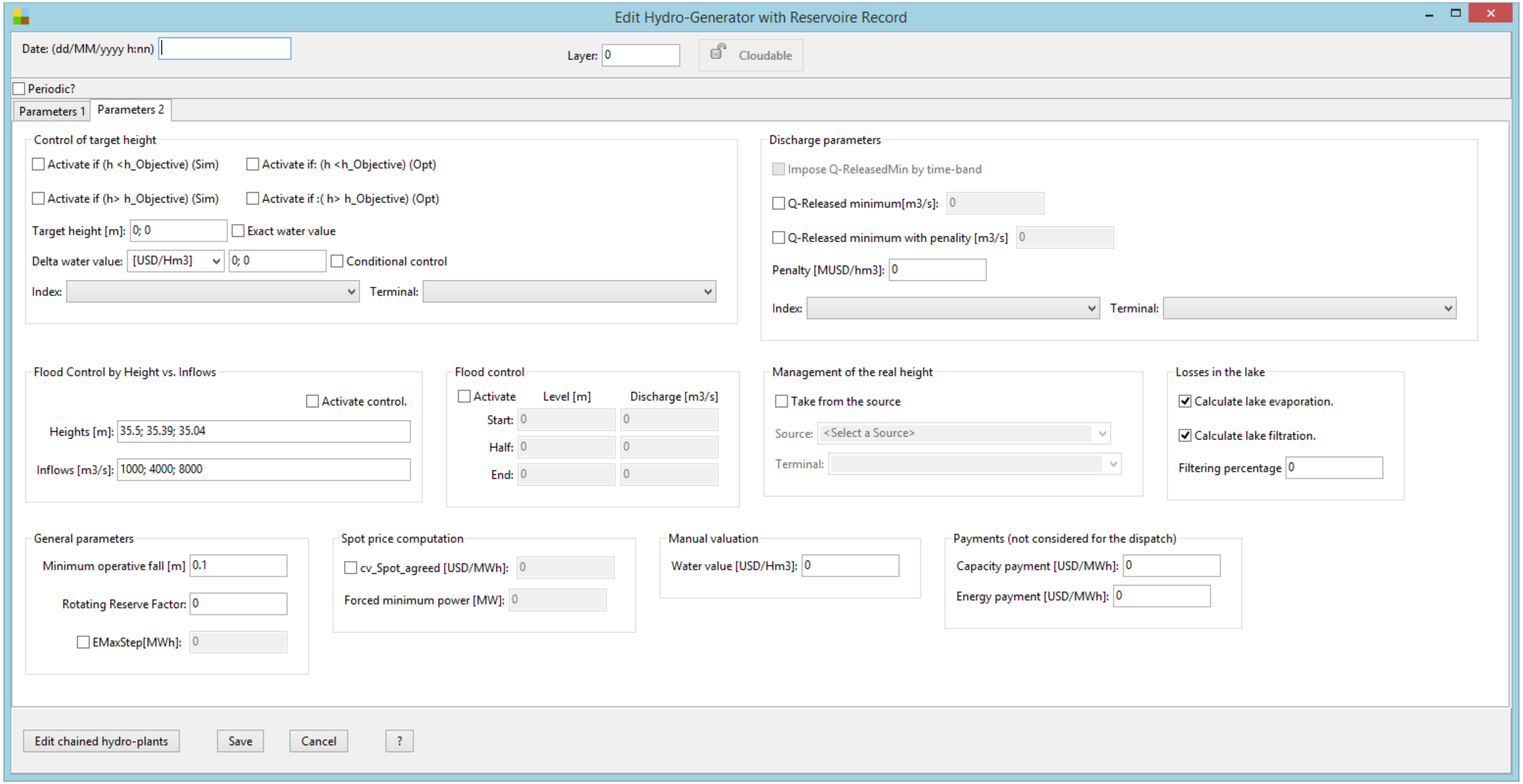
- $dh(Q_{released})$: variation of the effective jump based on the released water flow.
- $Q_{released}$: released water flow.

- Efficiency: It is the efficiency in p.u. of the turbines of the hydropower plant.
- Generable Maximun Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electricity Network.
- Maximum turbinable flow: It is the maximum flow in m3 / s that can be turbined.
- Availability factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- Average repair time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Ca and Cb filtration: They are the coefficients in m^3/s y m^2/s of the reservoir filtration. The filtration flow is calculated with ec.3.

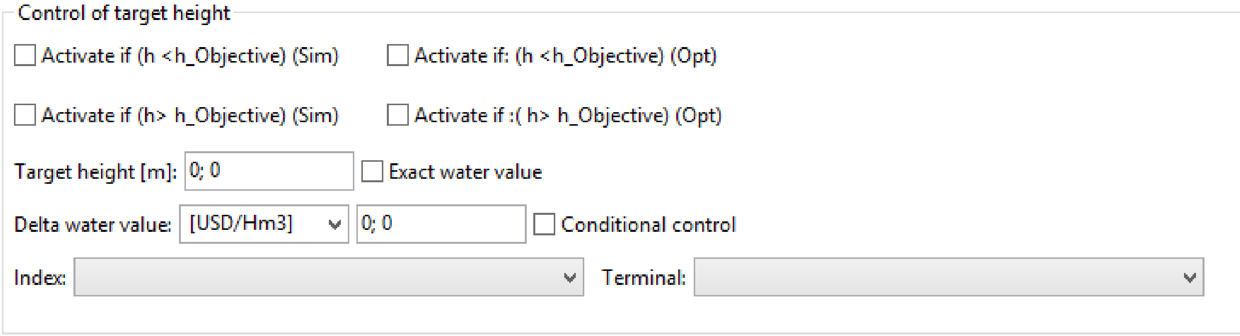
$$Q_{Filtration} = Ca_{Filtration} + Cb_{Filtration.} (h - h_{min})$$ ec.3 filtration flow.

- Qa very dry: It is the minimum flow in m^3/s required to generate energy.
- Minimum height for spilling: It is the height in m at which you can start the spilling.
- Height for maximum spillage: is the height at which the plant can spill the maximum water flow.
- Maximum controllable spillage flow: it is the maximum flow in m^3/s that can be spilled, under control, at the height of the maximum spillage (see the previous paragraph).

9.1.c.ii Parameters 2

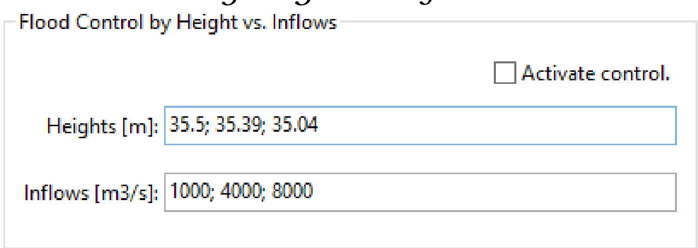


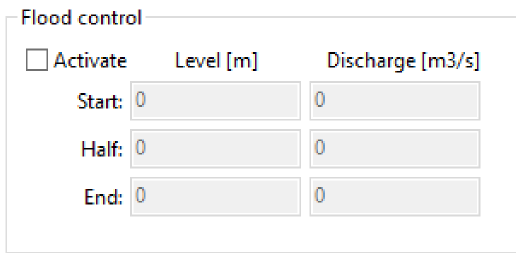
Control of Target height



The “Control of Target height” allows to specify a maximum or minimum target height, in the understanding that it will be economically penalized to exceed it (maximum height) or be below it (minimum height). The economic penalty is introduced as a “Delta water value”, choosing the unit (USD/hm^3 or USD/MWh) and defining the magnitude of the penalty. This value is added to the value of the water that is obtained from the optimization. If “Exact water value” is selected, the water value is directly replaced by the Delta value. If “Conditional Control” is selected, the highest value between the water value obtained from the optimization and the one defined in the Delta is assigned to the water value. The Index and Terminal are used to assign a Source to index the value defined in the Delta.

Flood control by height vs inflow and Flood control

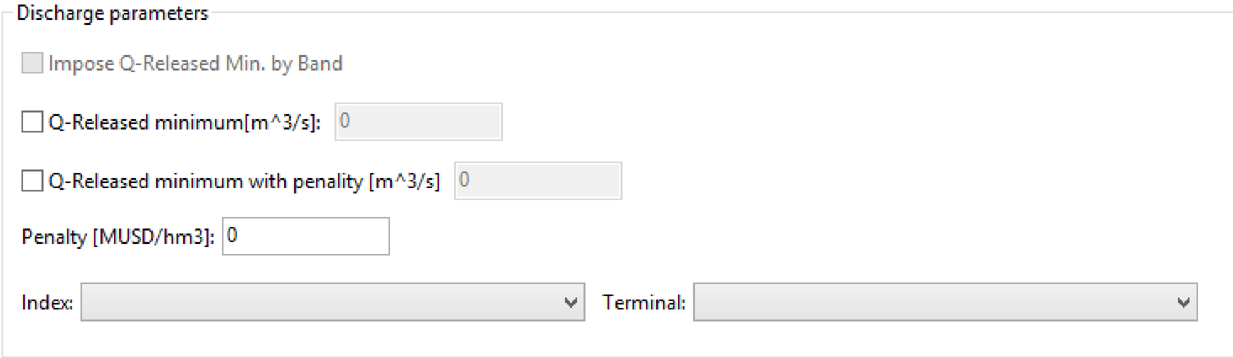




The “Flood control by height vs inflow” allows to specify a function, which relates the height of the lake and the values of the water inflow. This function is defined on the basis of 3 pairs of (height, inflow) values and is used to determine the released flow according to the inflow received, to comply with the corresponding height according to the function.

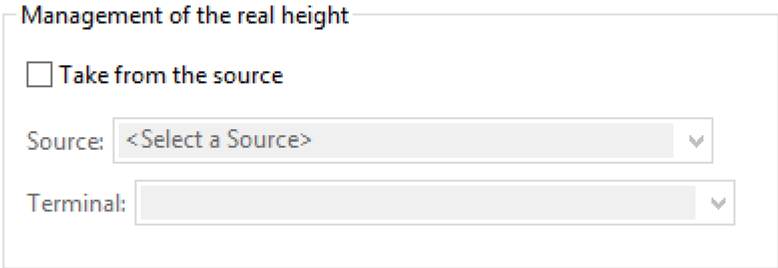
The "Flood Control" allows you to directly specify the released flow according to the height of the lake, regardless of the receiving inflow. For this, a pair of (height, discharge) values are defined in each box, where the first corresponds to the start of the control (specified start-up height), the second is a midpoint of operation and the third is a height of full released flow.

Discharge parameters



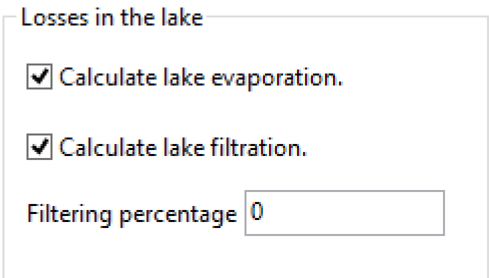
In “Discharge parameters” you can specify a minimum released flow by time Post or by time step (in order to enable downstream river navigation), a released flow with failure and a cost of failure (which can be indexed by Source, selecting the same in Index and Terminal).

Management of the real height



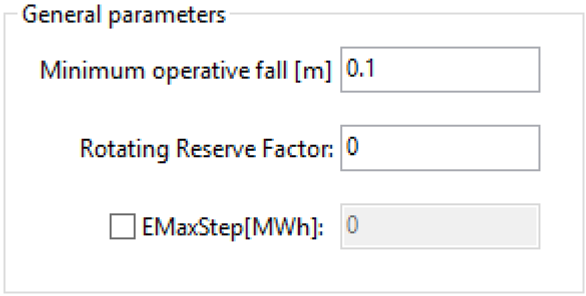
In “Management of the real height” you can define the real height h_{real} of the lake from a Source (specified in Source and Terminal).

Losses in the lake



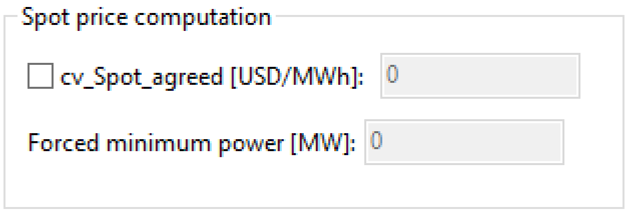
In “Losses in the lake” you select if you want to calculate the evaporation and filtration of water in the reservoir of the plant, selecting the corresponding box. If “Calculate lake filtration” is selected, the percentage of filtration to be applied to the result of ec.3 must be specified.

General parameters



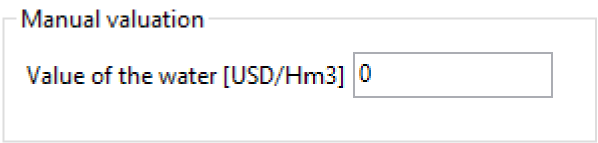
In "General parameters", you must define the minimum operating jump that the powerplant must have to operate together with the rotating reserve factor to be considered in the dispatch. It is also possible to impose a maximum energy output per time step (MWh).

Spot price computation



In "Spot price computation" you can define the Spot price of the Node, regardless of the water value of the plant assigned in the optimization, if the plant is marginalizing in the allocation of resources for the dispatch. In other words, if the plant is being dispatched to feed the last MW of energy required in the dispatch, the Spot price of the system is the value defined in the box instead of being the calculated water value. This condition is only activated if the power dispatched by the powerplant is higher than that specified in the "Minimum forced power" box.

Manual valuation



In "Manual valuation" it is possible to manually enter a water value in USD/hm^3 for the purpose of manually regulating the dispatch.

Attention, the value entered in USD/MWh is multiplied by 10 if the level is lower than the start of the simulation and divided by 10 if it is higher. This means that if there are resources in that range of values in the system, the lake will be operated trying to maintain the initial level.

9.1.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
QinflowP	m3/s	No	Yes	Water inflow stream.
QTurbined	m3/s	No	Yes	Turbined water flow
QDischarged	m3/s	No	Yes	Discharged water flow.
h_real	m	No	Yes	Intake height for calculating the performance of the plant. If Management of the real height is not activated then h_real = h.
h	m	No	Yes	Intake height of the reservoir lake (variable de estado del Actor).
ce	MWh/m3	No	Yes	Energy coefficient of the powerplant.
dh_RedQE	m	No	Yes	Variation of the effective jump based on the released water flow.
CV_waterDec	USD/hm3	No	Yes	Water Value calculated with the decremental derivative.
CV_waterInc	USD/hm3	No	Yes	Water value calculated with the incremental derivative.
Dual_QReleasedMin	USD/hm3	Yes	Yes	Dual of the constraints of minimum released flow.
hs_withoutReleasedflow	m	No	Yes	Projected height without released flow.
Vs_withoutReleasedflow	hm3	No	Yes	Projected volume without released flow.
Dual_dynamicConstraints _USDxhm3	USD/hm3	No	Yes	Dual of the dynamic constraints of the Actor.
CV_USD_MWh	USD/MWh	No	Yes	Generation Variable cost.
Discharge	hm3	No	Yes	Discharge volume.
Height	m	No	No	Intake height (state variable of the Actor).
Vol	hm3	No	Yes	Embalmed volume at the beginning of the time step.
NAvailableUnits	u	No	Yes	Number of available units in the time step.
QReleased	m3/s	No	No	Released water flow.
QEvaporation	m3/s	No	No	Evaporation flow losses.
QFiltration	m3/s	No	No	Filtration flow losses.
QReleasedFailure	m3/s	Yes	No	Dummy released flow to quantify the cost of not releasing the minimum required flow.
QTurbinedbyPost	m3/s	Yes	No	Turbinated flow per time post.
QDischargedbyPost	m3/s	Yes	No	Discharged flow per time post.

EMaxPost	MWh	Yes	No	Maximum energy dispatched per time post.

9.1.e) State variables, Control and Restrictions.

The Actor add 1 State Variables to the system.

- V : Volume of water in the reservoir in hm3.

The Actor adds 4 Control Variables per time post i :

- P_i : Power output.
- $Q_i^{Spillage}$: Spillage flow.
- $Q_i^{Discharge\,F}$: Discharge Failure flow.
- $P_i^{Rotating\,R}$: Rotating Reserve power.

The Actor adds the following constraints to the optimization problem:

In the case of the dispatch problem, it must be imposed the maximum and minimum volume constraint on the lake.

- $V_{fin,i} - V_{min,i} = V_{ini,i} + A_i - \sum_{j=1}^{j=NPost} \frac{P_{i,j} \cdot durpos_j}{ce} - Z_i - R_i - V_{min,i} \geq 0$
- $V_{max,i} - V_{fin,i} = V_{max,i} - \left(V_{ini,i} + A_i - \sum_{j=1}^{j=NPost} \frac{P_{i,j} \cdot durpos_j}{ce} - Z_i - R_i \right) \geq 0$

Constraints are also added depending on the conditions defined in the dynamic parameters Record of the Actor.

- Minimum released flow for navigability and safety of the dam.
- Minimum released flow with the possibility of failure.
- Maximum energy output per time step.

9.2. Hydropower Plant with Pumping.

The Hydropower Plant with Pumping is an Actor belonging to the Hydroelectrics Generators Group. This Actor is a particular type of hydropower plant with reservoir that has the possibility of pumping water from the river downstream to the lake of its reservoir.

9.2.a) Operation description.

The operation of the Hydropower Plant with Pumping as a power generating plant is identical to that of a Hydropower Plant with Reservoir, but with the possibility of determining the convenient moment to be able to pump water from the river downstream and increase the level of its reservoir. In the representation of the model, water pumping is an energy consumption and, in return, the dammed water is stored energy. Taking into account the state of the system and its inputs over time, the Future Cost function is calculated and the model determines whether or not to carry out the pumping.

To define the Actor it is necessary to specify the parameters of the reservoir and their respective restrictions in the limits of the volume of the water stored. A schematic representation of the plant is presented in Fig.1.
Where:

5. V : It is the volume of water in the reservoir.
6. h : It is the difference in height between the turbine drain and the downstream river surface.
7. dV : Is the turbinated volume.
8. dE : Is the energy produced by the generation units.

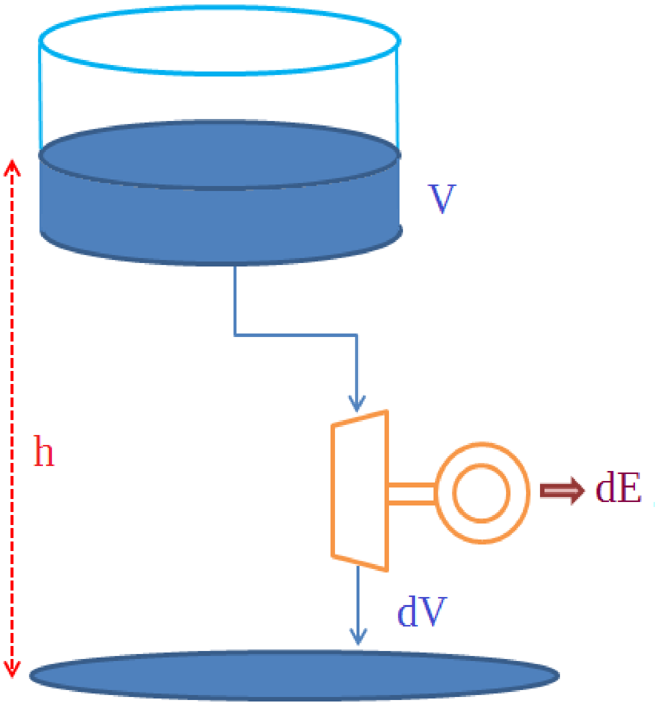


Fig. 11: Eschematic representation of the Hydropower Plant with Reservoir.

The volume V_{fin} at the end of the passage of time is calculated as the volume at the beginning V_{ini}, plus the volume that enters the lake due to the inflows of its own basin or by flows released in upriver power plants A, minus the turbinated volumes in each time post, minus the spillage volume Z minus evaporation losses and filtration of the reservoir R.

The final volume is calculated with ec.1:

$$V_{fin}=V_{ini}+A-\sum_{j=1}^{j=NPostes}\frac{P_j durpos_j}{ce}-Z-R$$

ec.1 Final volume of the reservoir.

Where the turbinated volume in the time post j is: $\frac{P_j durpos_j}{ce}$, where ce is the energy coefficient and $P_j durpos_j$ is the power delivered in the time post j multiplied by the duration of the post j.

The energy coefficient is determined by the function $dE = ce.dV$, where it represents the conversion factor between a turbinated volume dV and the energy generated and delivered by the plant to the electricity grid dE .

Considering the height h , measured from the surface of the lake to the turbines exit, we can write the energy coefficient as:

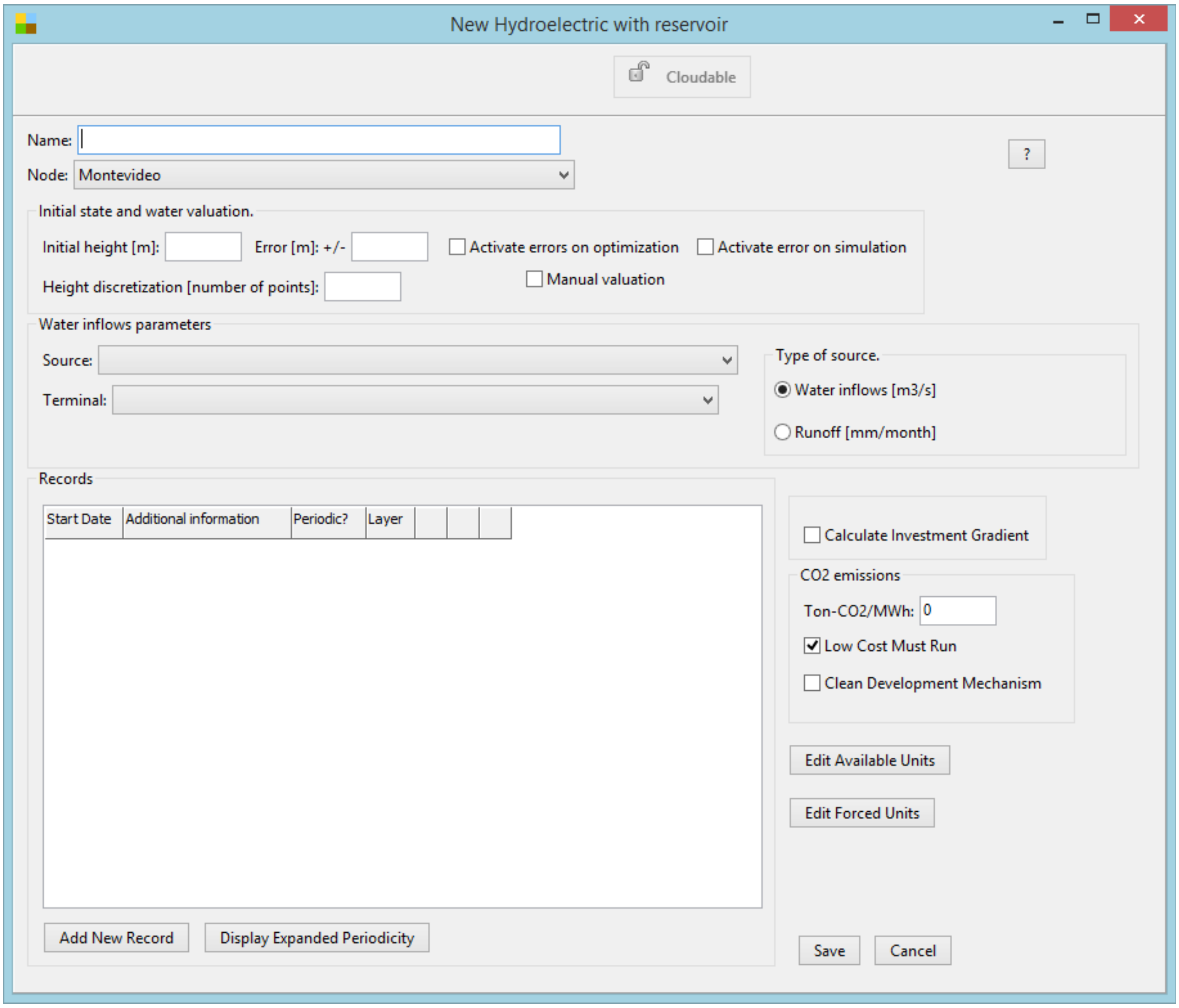
$$ce = h \cdot \rho \cdot g \cdot \eta$$

Where:

- ρ Is the water density. (1000kg/m^3)
- g Is the gravitational constant. (9.8m/s^2)
- η It is the complex performance of the turbine and the electric generator.

As can be seen, the turbine volume equation as a function of the power generated by the plant is an approximation since the energy coefficient varies depending on the useful jump h . The useful jump can vary depending on the level of the lake or by the variation of the level downstream, and the level downstream due to the turbinate itself. The energy coefficient also changes as the turbine efficiency varies, which is not constant for all flows.

The registration form of the Hydropower Plant with Reservoir is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

9.2.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network that you want to associate the Actor with, and the inical state of the system, which is defined from the specification of the parameters found within the panel "Initial state and value of the water".

Within the above panel the following parameters must be specified:

- Initial height: It is the initial height of the lake in m.
- Error: It is the error that you want to add to the initial height. If it is desired that said error be considered in simulation time and / or in optimization time, the corresponding box must be checked.

- Height discretization: It is the number of points to discretize the reservoir.
- Manual valuation: Check the box if you want to manually carry out the water valuation. Once selected, the desired water value must be defined in each Record within the “Manual valuation” panel within the “Parameters 2” parameters tab.

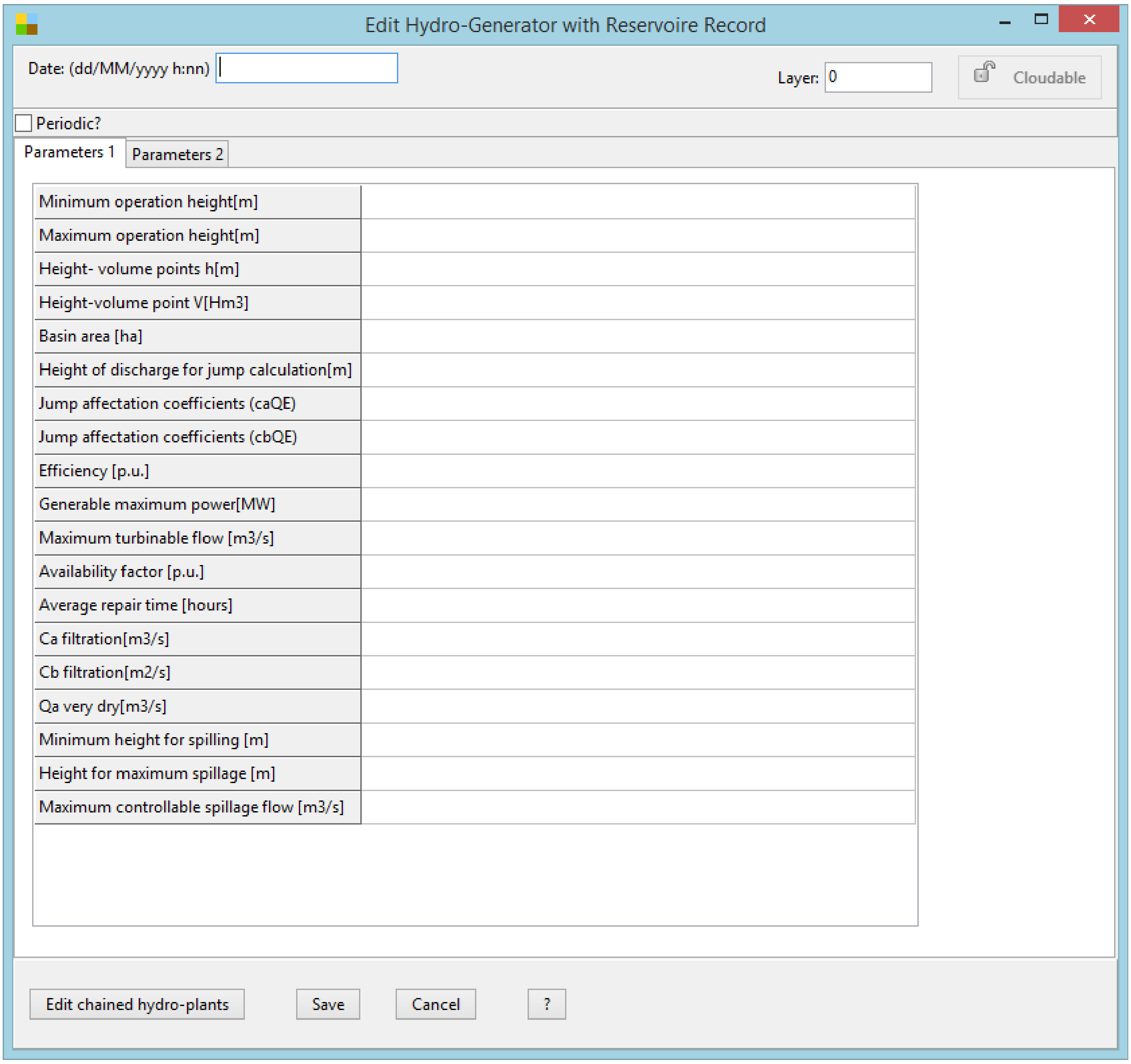
Within the panel "Water inflow parameters" a Source and Terminal can be specified, so that the Actor receives the information on the water inflow to the central basin. It must be specified if the source corresponds to inflow or filtration data within the basin.

9.2.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

For clarity, the registration panel of a Record is divided into two tabs called Parameters 1 and Parameters 2. Each tab of the registration panel of a Record is shown below:

9.2.c.i Parameters 1



The parameters to specify are:

- Minimum operation height: It is the minimum height in m of operation of the Reservoir.
- Maximum operation height: It is the maximum height in m of operation of the Reservoir.
- Height-volume points h: These are the height-volume points in m to determine the volume curve of the reservoir.
- Height-volume points V: These are the height-volume points in Hm3 to determine the volume curve of the reservoir.
- Basin area: It is the surface area in ha. which occupies the basin of the reservoir.
- Height of discharge for jump calculation: It is the height in m. of downstream discharge.
- Jump affectation coefficients (caQ_E , cbQ_E): These are coefficients used to model the reduction of the effective jump due to the released flow. This reduction affects the calculation of the energy coefficient (Ce). The effective jump is calculated with ec.2.

$$dh(Q_{released}) = caQ_E \cdot Q_{released} + cbQ_E \cdot (Q_{released})^2$$

ec.2 Effective jump for released flow.

Where:

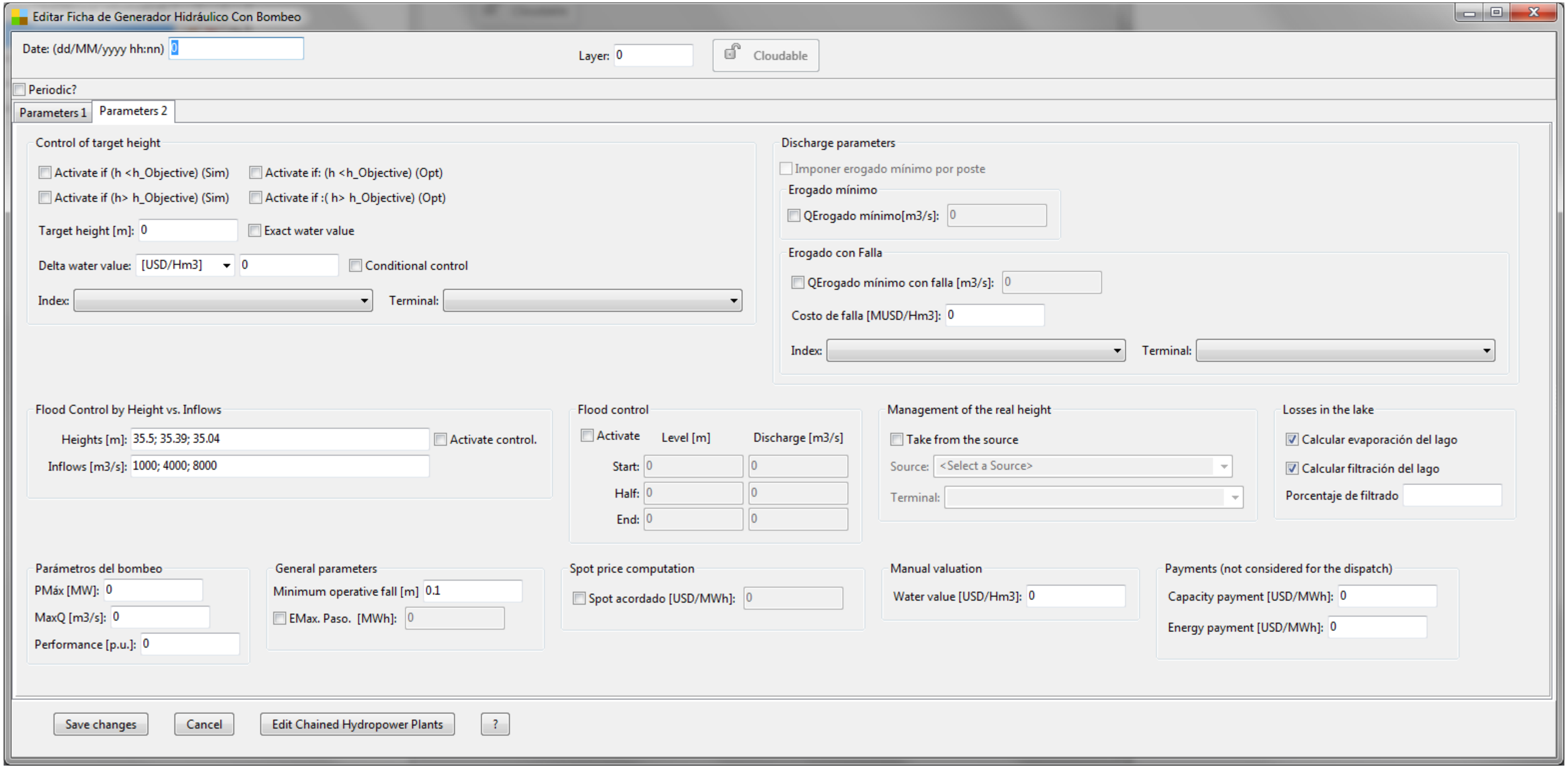
- $dh(Q_{released})$: variation of the effective jump based on the released water flow.
- $Q_{released}$: released water flow.

- Efficiency: It is the efficiency in p.u. of the turbines of the hydropower plant.
- Generable Maximun Power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electricity Network.
- Maximum turbinable flow: It is the maximum flow in m3 / s that can be turbined.
- Availability factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- Average repair time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Ca and Cb filtration: They are the coefficients in m^3/s y m^2/s of the reservoir filtration. The filtration flow is calculated with ec.3.

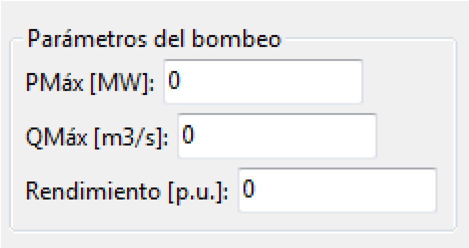
$$Q_{Filtration} = Ca_{Filtration} + Cb_{Filtration.} (h - h_{min})$$ ec.3 filtration flow.

- Qa very dry: It is the minimum flow in m^3/s required to generate energy.
- Minimum height for spilling: It is the height in m at which you can start the spilling.
- Height for maximum spillage: is the height at which the plant can spill the maximum water flow.
- Maximum controllable spillage flow: it is the maximum flow in m^3/s that can be spilled, under control, at the height of the maximum spillage (see the previous paragraph).

9.2.c.ii Parameters 2

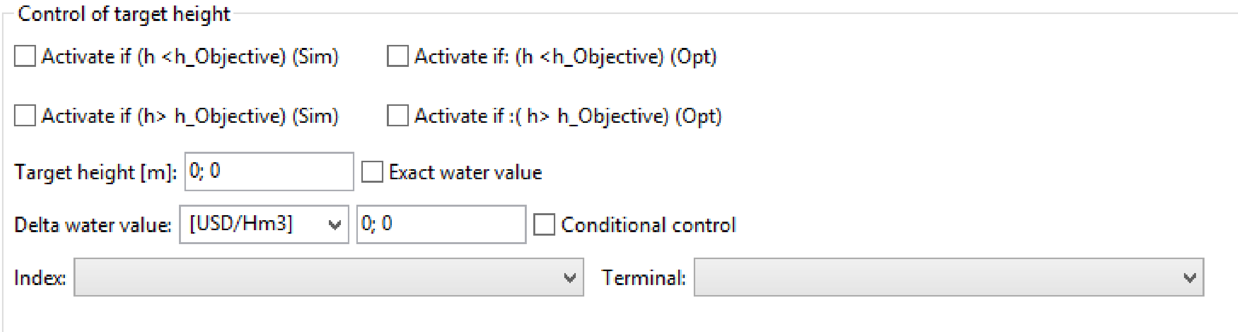


Pumping parameters



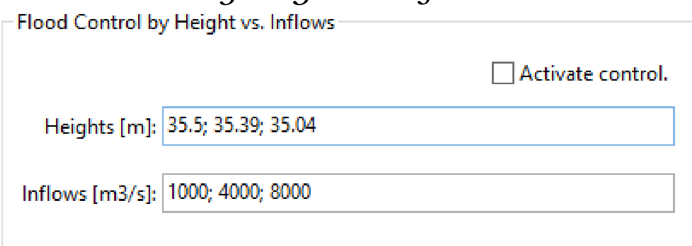
In "Pumping parameters" it is possible to specify the maximum power (Pmax) that the hidropower plant can pump, the maximum pump flow rate (Qmax) and the total performance of the pumping system (Performance).

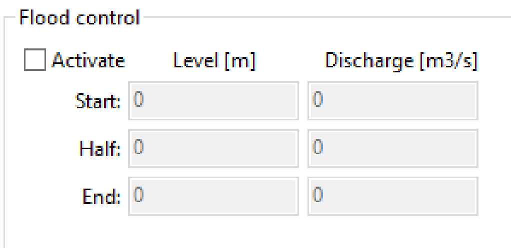
Control of Target height



The "Control of Target height" allows to specify a maximum or minimum target height, in the understanding that it will be economically penalized to exceed it (maximum height) or be below it (minimum height). The economic penalty is introduced as a "Delta water value", choosing the unit (USD/hm^3 or USD/MWh) and defining the magnitude of the penalty. This value is added to the value of the water that is obtained from the optimization. If "Exact water value" is selected, the water value is directly replaced by the Delta value. If "Conditional Control" is selected, the highest value between the water value obtained from the optimization and the one defined in the Delta is assigned to the water value. The Index and Terminal are used to assign a Source to index the value defined in the Delta.

Flood control by height vs inflow and Flood control

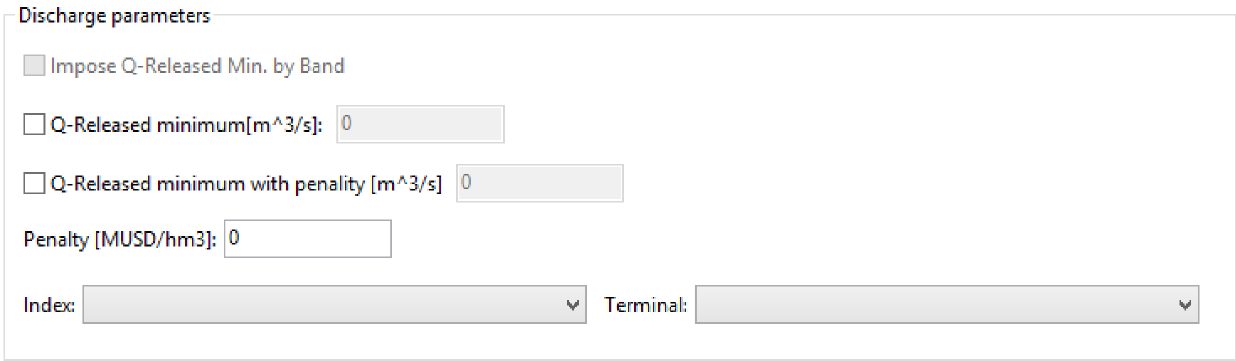




The "Flood control by height vs inflow" allows to specify a function, which relates the height of the lake and the values of the water inflow. This function is defined on the basis of 3 pairs of (height, inflow) values and is used to determine the released flow according to the inflow received, to comply with the corresponding height according to the function.

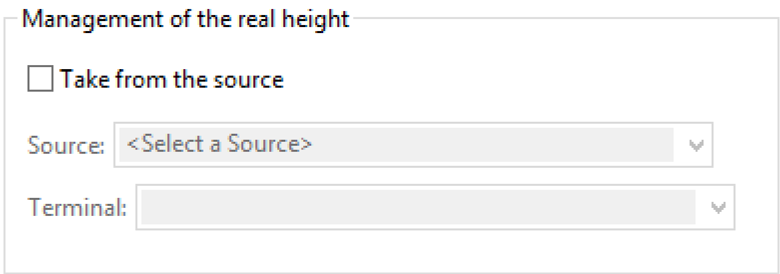
The "Flood Control" allows you to directly specify the released flow according to the height of the lake, regardless of the receiving inflow. For this, a pair of (height, discharge) values are defined in each box, where the first corresponds to the start of the control (specified start-up height), the second is a midpoint of operation and the third is a height of full released flow.

Discharge parameters



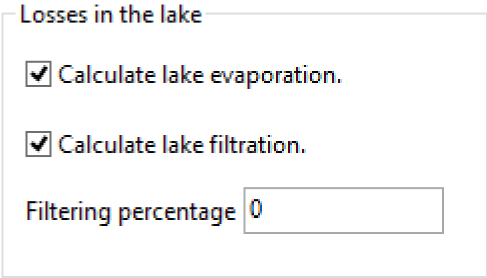
In “Discharge parameters” you can specify a minimum released flow by time Post or by time step (in order to enable downstream river navigation), a released flow with failure and a cost of failure (which can be indexed by Source, selecting the same in Index and Terminal).

Management of the real height



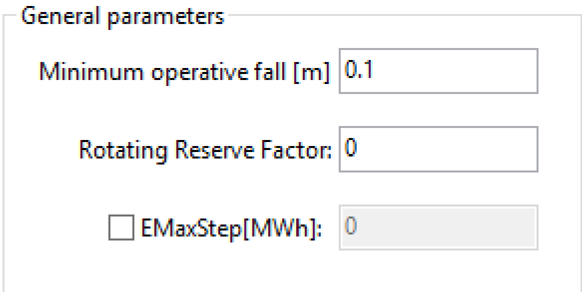
In “Management of the real height” you can define the real height h_{real} of the lake from a Source (specified in Source and Terminal).

Losses in the lake



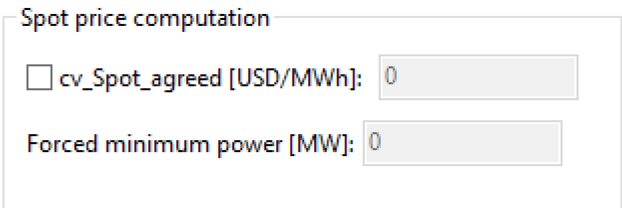
In "Losses in the lake" you select if you want to calculate the evaporation and filtration of water in the reservoir of the plant, selecting the corresponding box. If "Calculate lake filtration" is selected, the percentage of filtration to be applied to the result of ec.3 must be specified.

General parameters



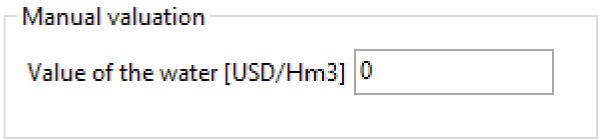
In "General parameters", you must define the minimum operating jump that the powerplant must have to operate together with the rotating reserve factor to be considered in the dispatch. It is also possible to impose a maximum energy output per time step (MWh).

Spot price computation



In "Spot price computation" you can define the Spot price of the Node, regardless of the water value of the plant assigned in the optimization, if the plant is marginalizing in the allocation of resources for the dispatch. In other words, if the plant is being dispatched to feed the last MW of energy required in the dispatch, the Spot price of the system is the value defined in the box instead of being the calculated water value. This condition is only activated if the power dispatched by the powerplant is higher than that specified in the “Minimum forced power” box.

Manual valuation



In “Manual valuation” it is possible to manually enter a water value in USD/hm^3 for the purpose of manually regulating the dispatch.

Attention, the value entered in USD/MWh is multiplied by 10 if the level is lower than the one at the start of the simulation and divided by 10 if it is higher. This means that if there are resources in that range of values in the system, the lake will be operated trying to maintain the initial level.

9.2.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
QinflowP	m3/s	No	Yes	Water inflow stream.
QTurbined	m3/s	No	Yes	Turbined water flow
QDischarged	m3/s	No	Yes	Discharged water flow.
h_real	m	No	Yes	Intake height for calculating the performance of the plant. If Management of the real height is not activated then h_real = h.
h	m	No	Yes	Intake height of the reservoir lake (variable de estado del Actor).
ce	MWh/m3	No	Yes	Energy coefficient of the powerplant.
dh_RedQE	m	No	Yes	Variation of the effective jump based on the released water flow.
CV_waterDec	USD/Hm3	No	Yes	Water Value calculated with the decremental derivative.
CV_waterInc	USD/Hm3	No	Yes	Water value calculated with the incremental derivative.
Dual_QReleasedMin	USD/hm3	Yes	Yes	Dual of the constraints of minimum released flow.
hs_withoutReleasedflow	m	No	Yes	Projected height without released flow.
Vs_withoutReleasedflow	Hm3	No	Yes	Projected volume without released flow.
Dual_dynamicConstraints _USDxHm3	USD/Hm3	No	Yes	Dual of the dynamic constraints of the Actor.
CV_USD_MWh	USD/MWh	No	Yes	Generation Variable cost.
Discharge	Hm3	No	Yes	Discharge volume.
height	m	No	No	Intake height (state variable of the Actor).
Vol	Hm3	No	Yes	Embalmed volume at the beginning of the time step.
NAvailableUnits	u	No	Yes	Number of available units in the time step.
QReleased	m3/s	No	No	Released water flow.
QEvaporation	m3/s	No	No	Evaporation flow losses.
QFiltration	m3/s	No	No	Filtration flow losses.
QReleasedFailure	m3/s	Yes	No	Dummy released flow to quantify the cost of not releasing the minimum required flow.
QTurbinedbyPost	m3/s	Yes	No	Turbinated flow per time post.
QDischargedbyPost	m3/s	Yes	No	Discharged flow per time post.
EMaxPost	MWh	Yes	No	Maximum energy dispatched per time post.

9.2.e) State variables, Control and Restrictions.

The Actor add 1 State Variables to the system.

- V : Volume of water in the reservoir in Hm3.

The Actor adds 4 Control Variables per time post i :

- P_i : Power output.
- $Q_i^{Spillage}$: Spillage flow.
- $Q_i^{Discharge\ F}$: Discharge Failure flow.
- $P_i^{Rotating\ R}$: Rotating Reserve power.

The Actor adds the following constraints to the optimization problem:

In the case of the dispatch problem, it must be imposed the maximum and minimum volume constraint on the lake.

- $V_{fin,i} - V_{min,i} = V_{ini,i} + A_i - \sum_{j=1}^{j=NPost} \frac{P_{i,j} \cdot durpos_j}{ce} - Z_i - R_i - V_{min,i} \geq 0$
- $V_{max,i} - V_{fin,i} = V_{max,i} - \left(V_{ini,i} + A_i - \sum_{j=1}^{j=NPost} \frac{P_{i,j} \cdot durpos_j}{ce} - Z_i - R_i \right) \geq 0$

Constraints are also added depending on the conditions defined in the dynamic parameters Record of the Actor.

- Minimum released flow for navigability and safety of the dam.
- Minimum released flow with the possibility of failure.
- Maximum energy output per time step.

9.3. Run-of-River Hydropower Plant.

The Run-of-River Hydropower plant is an Actor belonging to the Thermal Generators Group. The role of the Actor is to model hydropower plants without a reservoir for energy storage, with only the possibility of generating energy from the inflow water stream.

9.3.a) Operation description.

Being a run-of-river plant, all the water that reaches the plant must be turbinated (electric power generation) or spillaged. It must be fulfilled that at each time post, the turbined flow plus the spillaged flow is equal to the inflow. Due to the lack of reservoir, evaporation or filtration losses are not considered possible.

A schematic representation of the plant is presented in Fig.1.
Where:

9. Intake height: It is the height where the plant takes water.
10. Discharge height: It is the height where the plant relesases water.
11. Jump: It is the jump and is determined by the subtraction between the inlet level and the outlet level.
12. dE : Is the energy produced by the generation units.

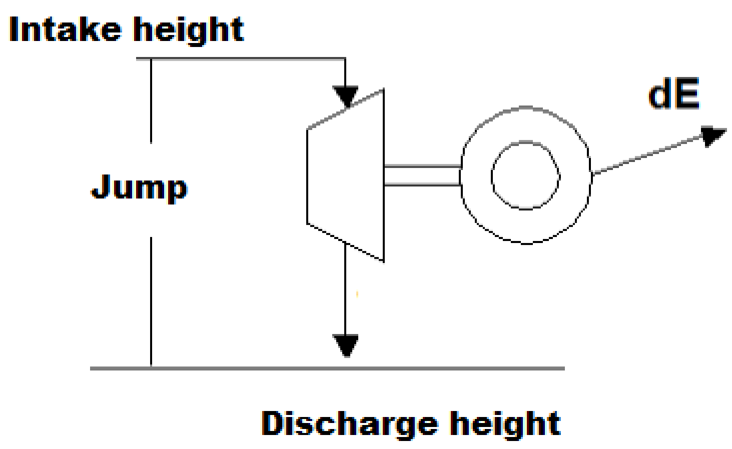
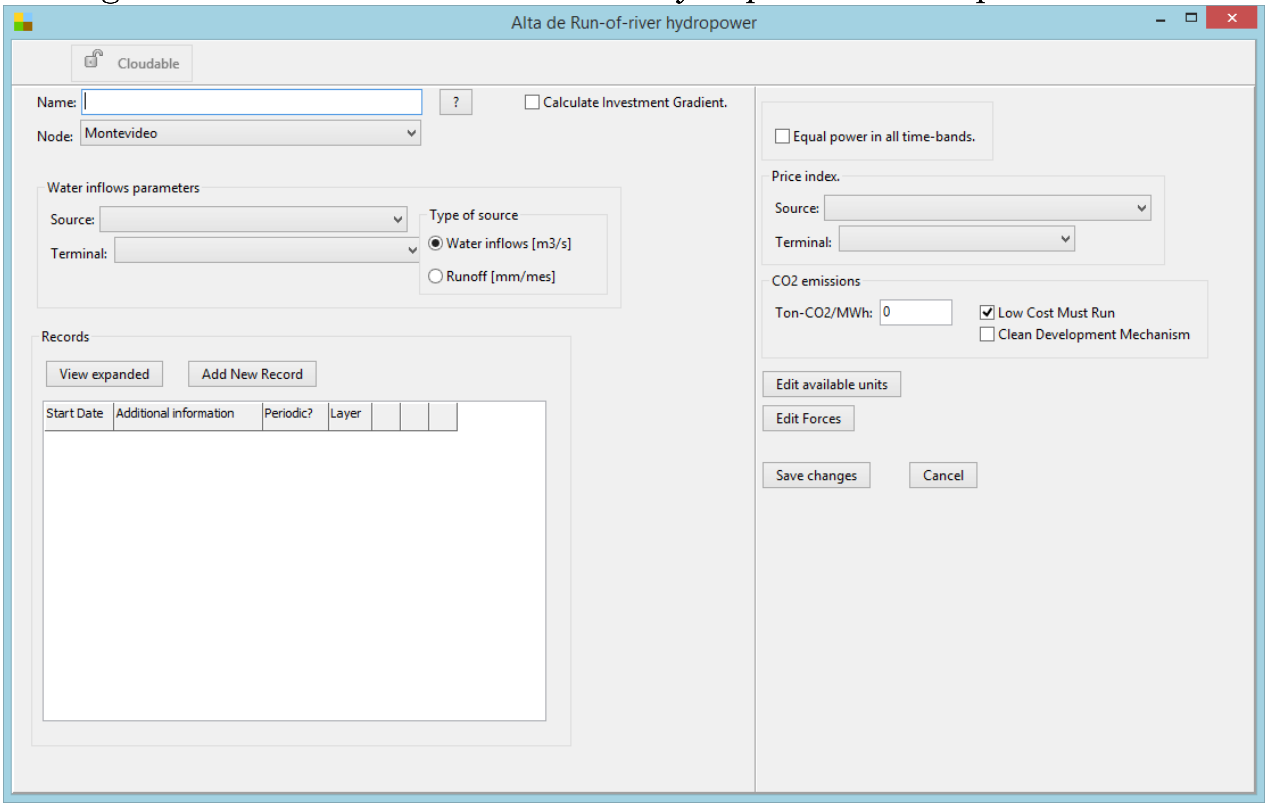


Fig. 12: Schematic representation of the Run-of-River Hydropower Plant.

To the plant enters a water inflow that can be the sum of the inflows to its basin and released flows by upstream hydropower plants. The intake height of the plant is fixed and the discharge height can be fixed or it can be the level of the lake of another plant located downstream.

The registration form of the Run-of-River Hydropower Plant is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

9.3.b) *Static parameters.*

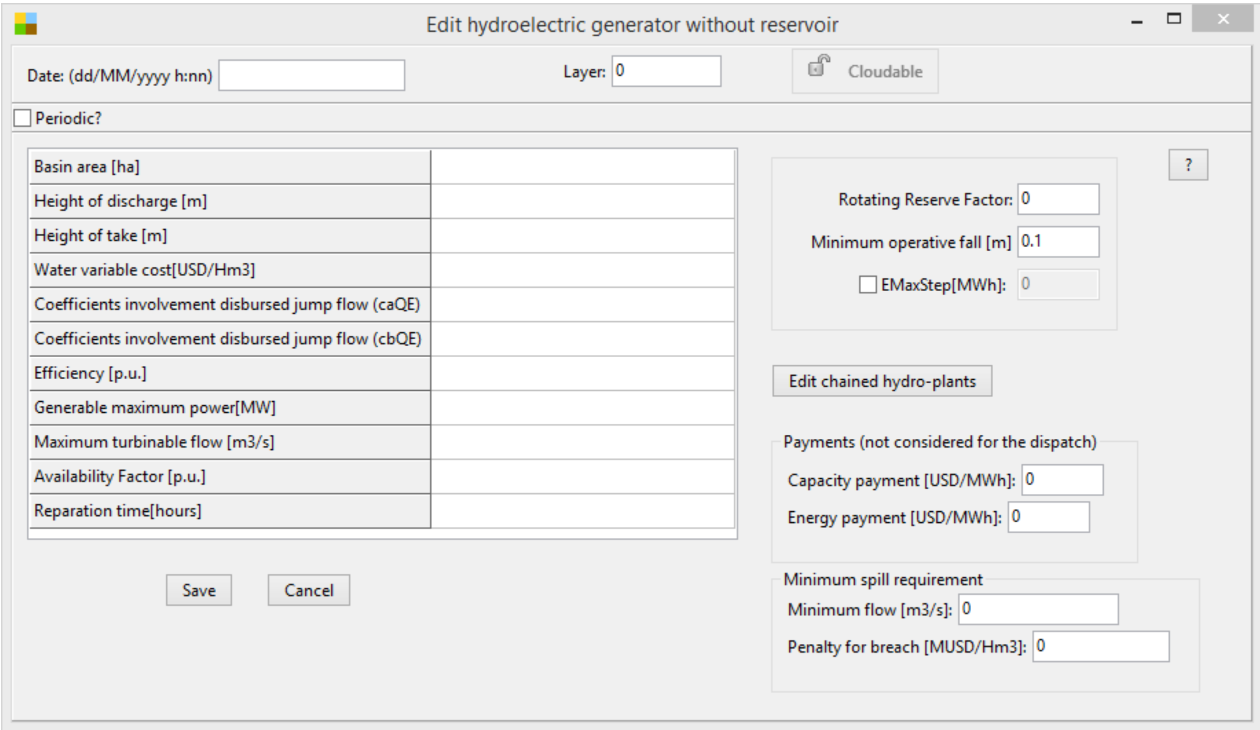
The static parameters are the Name and Node of the Electric Network with which you want to associate the Actor.

Within the panel "Water inflow parameters" a Source and Terminal can be specified, so that the Actor receives the information on the water inflow to the central basin. It must be specified if the source corresponds to inflow or runoff data within the basin.

If it is desired that the Actor generates the same power in all time posts, the corresponding box “Equal power in all time-bands” must be checked.

9.3.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.



The parameters to specify are:

- Basin area: It is the surface area in ha. which occupies the basin of the reservoir.
- Height of take: It is the height where the plant takes water.
- Height of discharge: It is the height where the plant relesases water.
- Water variable cost: It is the value of water in USD/MWh. This value is usually set at 0 USD/MWh so that the plant, as long as it has inflow, can generate electricity.
- Jump affectation coefficients (caQ_E , cbQ_E): These are coefficients used to model the reduction of the effective jump due to the released flow. This reduction affects the calculation of the energy coefficient (Ce). The effective jump is calculated with ec.2.

$$dh(Q_{released}) = caQ_E \cdot Q_{released} + cbQ_E \cdot (Q_{released})^2$$

ec.2 Effective jump for released flow.

Where:

- $dh(Q_{released})$: variation of the effective jump based on the released water flow.
  $Q_{released}$: released water flow.

- Efficiency: It is the efficiency in p.u. of the turbines of the hydropower plant.

- Generable maximum power: Maximum power in MW that the Actor can generate and deliver to the Node of the Electricity Network.
- Maximum turbinable flow: It is the maximum flow in m3 / s that can be turbined.
- Availability factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- Average repair time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Minimum operating fall: Is the minimum operating jump in m that the powerplant must have to operate.
- Rotating reserve factor: Is the rotating reserve factor to be considered in the dispatch.
- EmaxStep: Is the maximum energy output per time step in MWh.
- In the panel "Minimum spill requirement" a minimum spillage flow can be specified per time Post or per time step (in order to enable navigation downstream) and a penalty (which can be indexed by a Source, selecting the same in Index and Terminal).

9.3.d) Published variables for SimRes.

The Actor allows to publish the following variables:Actor allows to publish the following variables:

Name	***Unit***	***Time***	***SR3***	***Description***

		post		
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
QinflowP	m3/s	No	Yes	Water inflow stream.
QTurbined	m3/s	No	Yes	Turbined water flow
QDischarged	m3/s	No	Yes	Discharged water flow.
Jump	m	No	Yes	Jump determined by the subtraction between the inlet level and the outlet level.
ce	[MWh/m3]	No	Si	Energy coefficient
dh_RedQE	m	No	Yes	Variation of the effective jump based on the released water flow.
cv_USD_MWh	USD/MWh	No	Yes	Generation Variable cost.
cv_water_MLRB	USD/Hm3	No	Yes	Negative of the Lagrange multiplier (- λ) of the flow balance restriction.
Cota	m	No	Si	
VVertido	Hm3	No	No	Volumen vertido en el paso.
Dual_Vertimiento	USD/Hm3	No	Si	Dual de la restricción de caja del vertimiento.
Pmax_Central	MW	No	Si	Potencia máxima disponible en el paso de tiempo.
VTurbinado	Hm3	No	No	Volumen turbinado en el paso.
NMaqsDisponibles	u	No	Si	Cantidad de máquinas disponibles del paso.
QTrubinadoPorPoste	m3/s	Sí	Si	Caudal turbinado por poste.

9.3.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 4 Control Variables per time post i :

- P_i : Power output.
- $Q_i^{Spillage}$: Spillage flow.
- $Q_i^{Discharge\,F}$: Discharge Failure flow.
- $P_i^{Rotating\,R}$: Rotating Reserve power.

The Actor adds the following constraints to the optimization problem:

The water flow balance constraint on each time post.

- $0=A_i-\sum_{j=1}^{j=NPostes}\frac{P_{i,j}\cdot durpos_j}{ce}-Z_i$

  Where:
  A : Is the volume that enters the lake due to the inflow of its own basin or by flows released in upriver power plants.
  $\frac{P_j durpos_j}{ce}$: Is the turbinated volume in the time post j , where ce is the energy coefficient and $P_j durpos_j$ is the power delivered in the time post j multiplied by the duration of the post j .
- Z : Is the spillage volume.

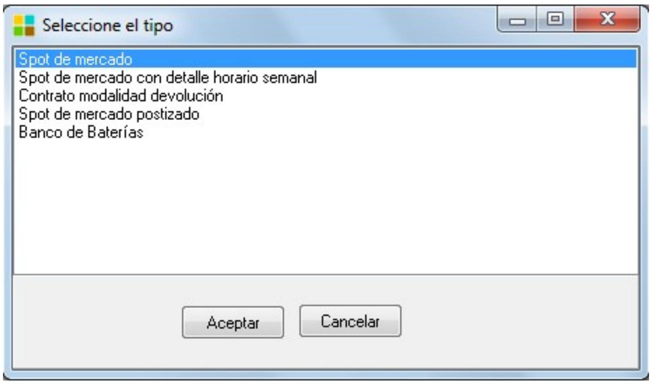
Constraints are also added depending on the conditions defined in the dynamic parameters Record of the Actor.

- Minimum released flow for navigability.
- Minimum released flow with the possibility of failure.
- Maximum energy output per time step.
- Equal power in all posts.

10. International Group and Others

With the group of Actors of the International Group and Others tab, it is possible to model different types of modalities and capacities for energy exchanges with neighboring countries.

The figure below shows the different types of international trade actors that are available in SimSEE.

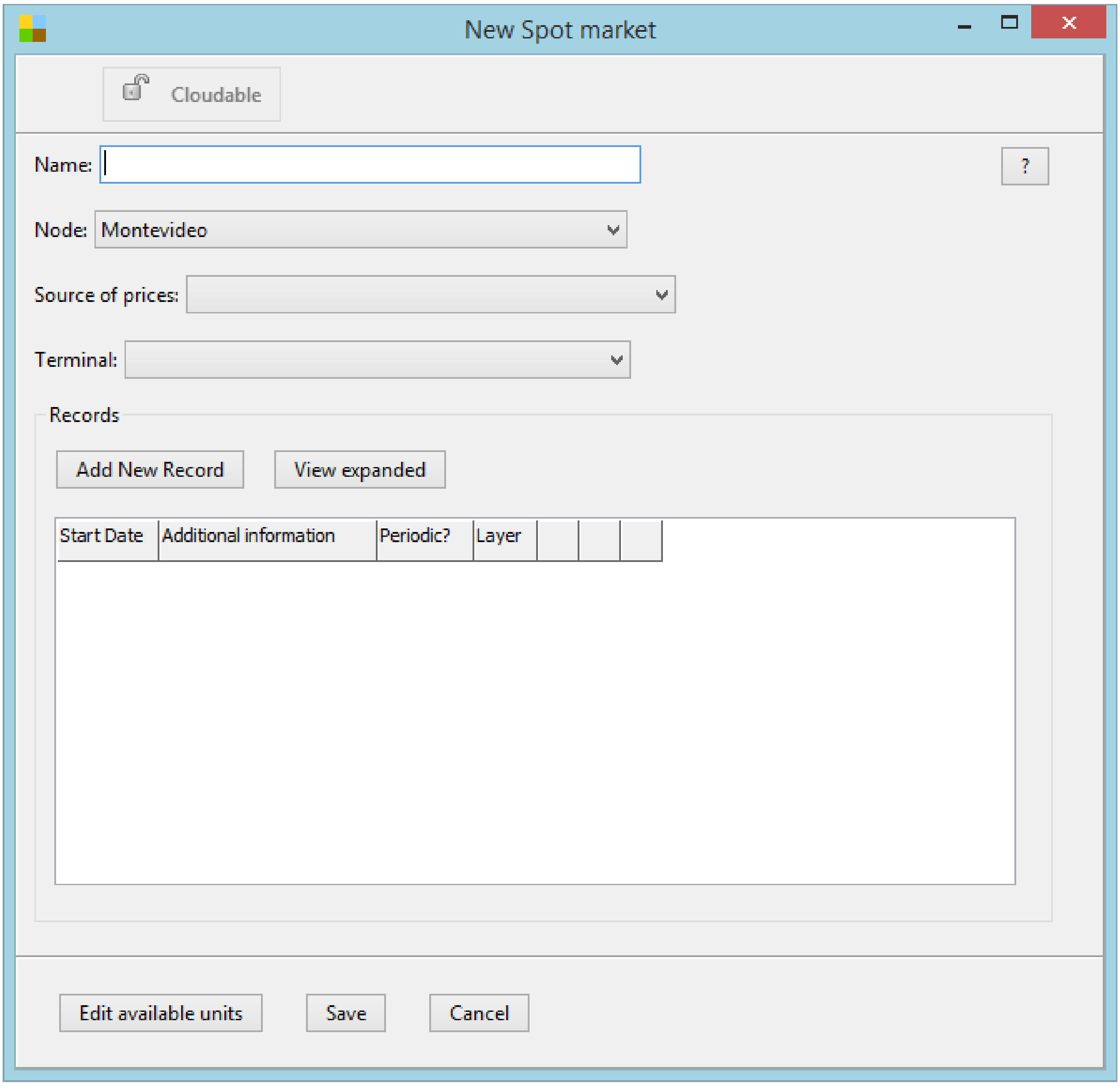


10.1. Spot Market.

The Spot Market is an Actor that belongs to the International and Others Group. This Actor can deliver (import) or withdraw (export) energy from the Node to which it is connected. A source of market Spot prices must be specified and in the case that it is fulfilled that the price of the energy in the connection node is higher than the price of the source, the energy available in the Node is imported and otherwise it is exported.

10.1.a) Operation description.

The registration form of the Spot Market is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

10.1.b) *Static parameters.*

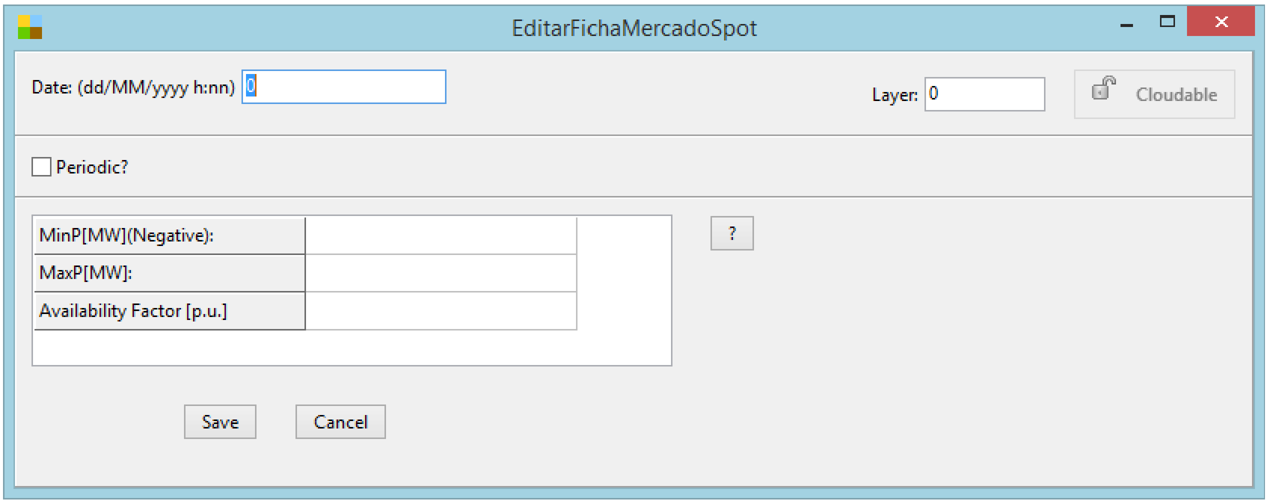
The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

In the Source of Prices, the Source and Terminal associated to the spot market price in USD/MWh must be specified.

10.1.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- MinP: It is the minimum (negative) value of power in MW that the actor can exchange with the node to which it is connected. It must be less than or equal to zero so that the actor can withdraw (export) energy from the node to which it is connected. The absolute value of Pmin is therefore the maximum power that the node can export to the market.

- MaxP: It is the maximum (positive) value of power in MW that the actor can exchange with the node to which it is connected. It must be greater than or equal to zero so that the actor can inject energy to the node to which it is connected. The Pmax value is therefore the maximum power that the node can import from the market.
- Availability Factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.

10.1.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
Cost	USD	Yes	Yes	Total cost incurred by the actor due to the exchange of energy with the network connection node.
cv	USD/MWh	No	Yes	Spot Market Price

10.1.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor add 1 Control Variables:

- P_i : Power injected to the node.

The Actor adds the following restrictions to the optimization problem:

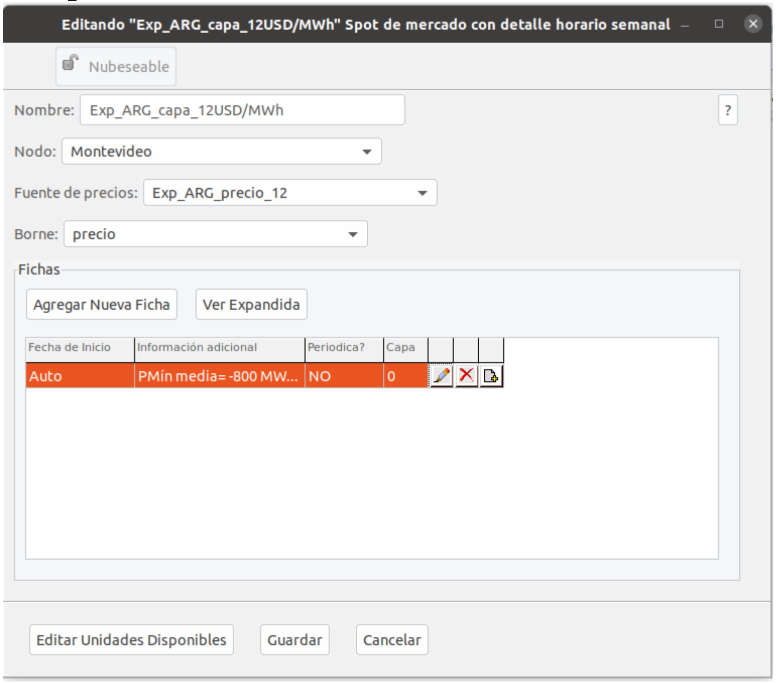
- Node power restriction.

10.2. *Spot Market with Weekly Hourly Detail.*

The Spot Market with Weekly Hourly Detail is an Actor that belongs to the International and Others Group. This Actor has the possibility to specify the information of the spot market for each hour of the week.

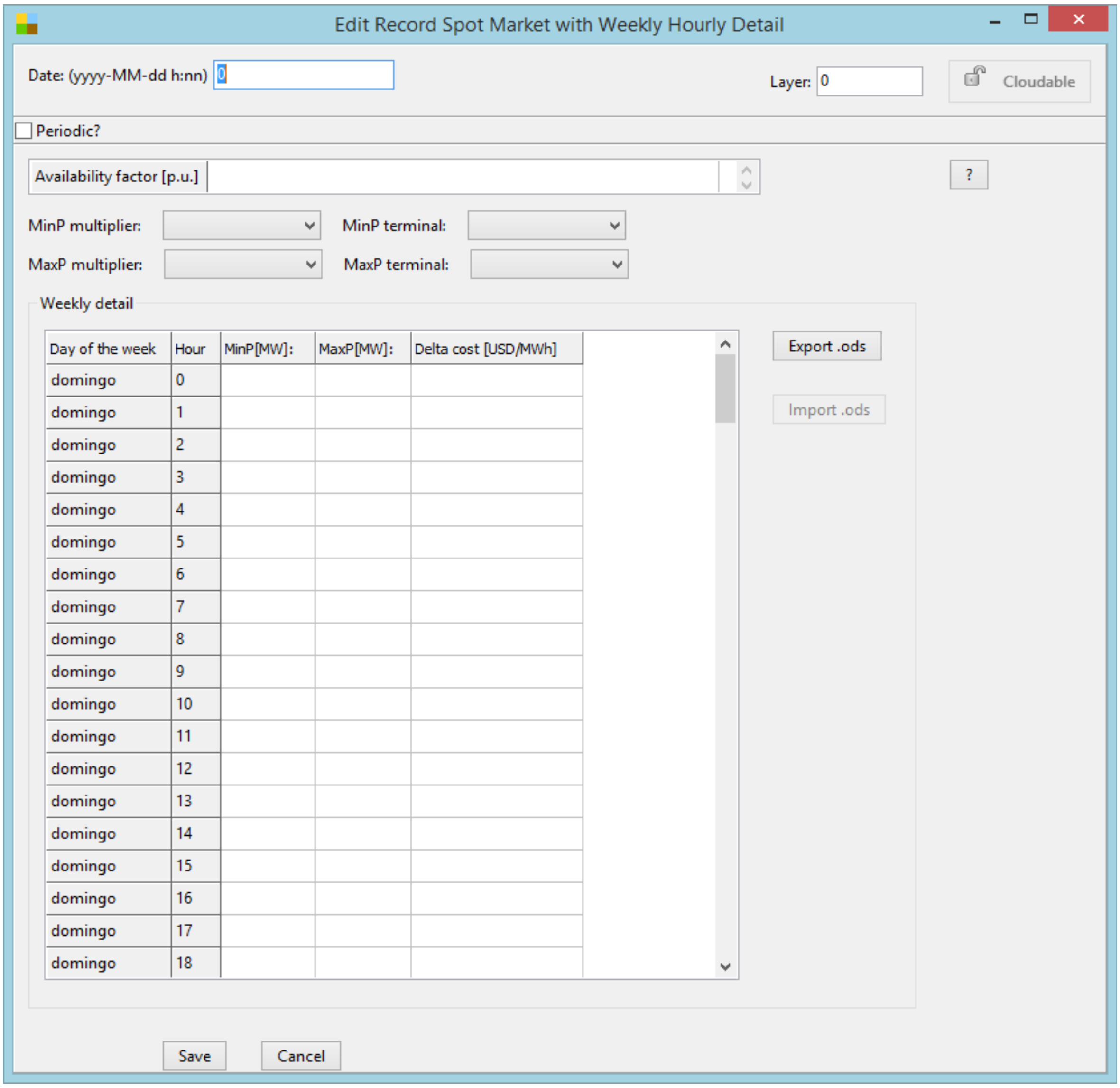
10.2.a) *Static parameters.*

The static parameters are the Generator Name, the Node of the Electric Network with which you want to associate the Actor and the source (and terminal) of market prices.



10.2.b) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel. The registration panel of a new Record is shown below:



The technical parameters to specify are:

General parameters:

- Availability Factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.

In the "Weekly detail" panel you must specify:

- For each day and time of the week (168 hours) a minimum power value (MinP) and maximum power (MaxP) in MW that can be commercialized in the spot market.
- The price at which the transaction is made, in each hour, will be given by the value of the Price Source (static parameter of the Actor) plus the **Delta cost** value specified in USD/MWh for the hour in question. In the case of time steps subdivided into Posts of several hours, the exchange price is

calculated as the price of the Price Source at the beginning of the time step plus the average of the **Delta cost** values of each Post.

- It is possible to add a multiplier of the minimum and maximum power values to multiply data of MinP and MaxP entered in the Record. The multiplier must be selected in the drop-down window and in the corresponding terminal.

Remember that if you want to model the possibility of exporting energy, the minimum power value must be negative.

To facilitate the edition of the weekly hourly data, it is possible to export/import the information to a form, using the “Export.ods” / “Import.ods” buttons.

10.2.c) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	*Unit*	*Time post*	*SR3*	*Description*
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
Cost	USD	Yes	Yes	Total cost incurred by the actor due to the exchange of energy with the network connection node.
cv	USD/MWh	No	Yes	Spot Market Price

10.2.d) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor add 1 Control Variables per time-band i :

- $Pi_{Node-Market}$: Power injected by the Node to the Market.
- $Pi_{Market-Node}$: Power delivered by the Market to the Node.

The Actor adds the following restrictions to the optimization problem:

- Node power restriction.
- Maximum and minimum power restrictions per hour.

11. Contract in Refund Mode.

The Actor Contract in Refund Mode belongs to the Group International Group and Others. The contract that the Actor implements allows to import or export energy at one time of the year with the commitment to return the energy at another time of the year. This type of Actor adds a state variable to the system that represents the energy that could be imported in the remainder of the year in this mode.

11.1. Function description.

The model created in SimSEE allows to set a time window in which energy and maximum volume can be imported, and another time window in which said energy must be returned. In both windows it is possible to specify the power limits for the exchange.

The imported energy, multiplied by an increment factor must be returned (exported) in the time window established for the return. In the event that it is not possible to return all imported energy, a penalty is applied for the remaining energy not returned at the end of the return time window.

The Actor adds a state variable called "Energy Credit (MWh)" ($E_{Credito}[k]$) that is defined as the difference between the maximum amount of energy that can be imported (E_{MaxImp}) in the contract minus the energy actually imported.

This model has three phases:

- Import
- Return
- Inert (when you are not in any of the previous phases)

For every step k of time you must meet:

$$0 \leq E_{Credito}[k] \leq E_{MaxImp}$$

In the Import phase, the contract acts as a generator that offers powers P_i at the time-bands of the time-step with a maximum P_{MaxImp} .

When the time passes, the remaining credit is calculated as follows:

$$E_{Credito}[k+1] = E_{Credito}[k] + dE_{Credito}[k] \geq 0$$

$$dE_{Credito}[k] = -\sum (P_i[k].durPos_i / ren_{Imp}).fi$$

Being $durPos_i$ the duration of the post within the time step and ren_{Imp} the import performance.

In the Import phase, the actor adds the following expression to the cost function:

SimSEE

$$c[k]=dE_{Imp}/f_i.cv_{Imp}+dCF/dE_{Credito}.dE_{Credito}[k]$$

Being:

- $dCF/dE_{Credito}$: Derived from Future Cost CF with respect to the state variable $E_{Credito}$. This derivative is calculated at the end of the step k (or beginning of $k+1$) with the system in the same state as at the beginning of the step k .
- dE_{Imp} : Energy imported by the actor during the passage of time.
- f_i : Factor that increases the amount of energy to be returned.
- cv_{Imp} : Cost in USD / MWh associated with possible charges for tolls and other possible charges associated with importation.

Substituting $dE_{Credito}$ the following expression based on the P_i (control variables):

$$c[k]=\sum(P_i.durPos_i.(cv_{Imp}-dCF/dE_{Credito}.f_i)/ren_{Imp})$$

From the previous expression it appears that for the purposes of dispatch, the variable cost to consider to dispatch the contract in this phase is

$$(cv_{Imp}-dCF/dE_{Credito}.fi)/ren_{Imp}$$

In the Return phase, the contract offers powers P_i (negative as they are demands) in each post of the passage of time, bounded by the maximum export power P_{MaxExp} . The following restriction must be met or each k :

$$0\leq E_{Credito}[k]\leq E_{MaxImp}$$

When the time passes, the remaining credit is calculated as follows:

$$E_{Credito}[k+1]=E_{Credito}[k]+dE_{Credito}[k]\geq 0$$
$$dE_{Credito}[k]=-\sum(P_i[k].durPos_i.ren_{\exp})$$

When the Return phase ends, the remaining energy must be paid at the cost of return ($cv_{Devolucion}$) to cancel the debt. The cost that the actor adds to the global cost function is as follows:

$$c[k]=-cv_{\exp}/ren_{\exp}.dE_{Credito}[k]+dCF/dE_{Credito}.dE_{Credito}[k]$$
$$+u.(EMaxImp-(E_{Credito}[k]+dE_{Credito}[k]))*cv_{Devolucion}$$
$$¿(-cv_{\exp}/ren_{\exp}+dCF/dE_{Credito}-u.cv_{Devolucion}).dE_{Credito}[k]+u.(EMaxImp-E_{Credito}[k]).cv_{Devolucion}$$

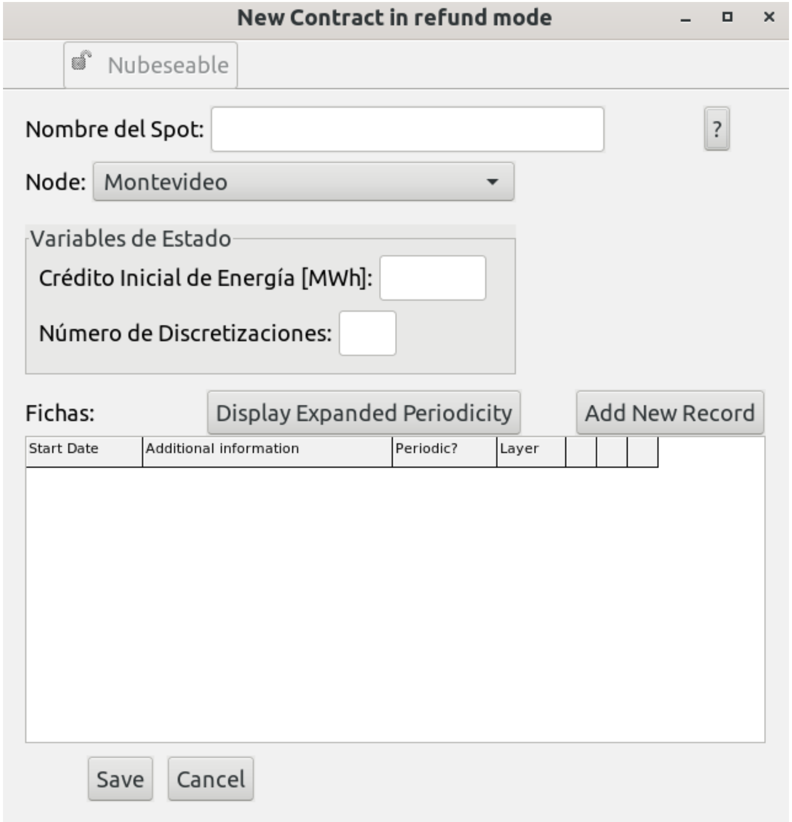
Being $u=1$ if the start of the next step is outside the return window and $u=0$ otherwise.

Substituting $dE_{Credito}[k]$ according to the P_i (control variables) it is:

$$c[k]=\sum \left(durPos_i . ren_{\exp} . \left(cv_{\exp} / ren_{\exp} - dCF / dE_{Credito} + u . cv_{Devolucion}\right) . P_i\right) + u . \left(E_{MaxImp} - E_{Credito}[k]\right) . cv_{Devolucion}$$

In the Inert phase, the contract does not intervene, except in the state space in which the amount of energy to be returned must be reflected.

The registration form of the Contract in Refund Mode is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

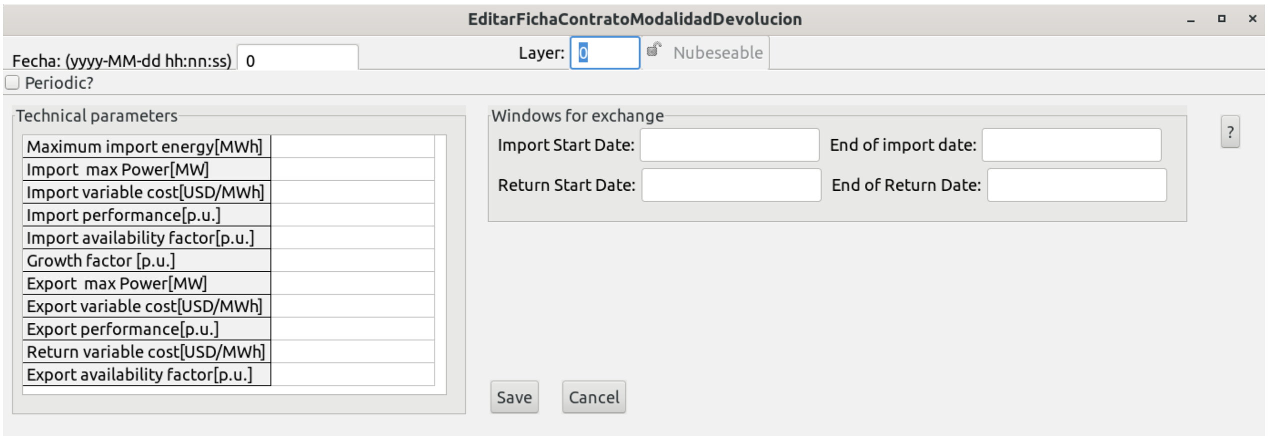
11.2. Static parameters.

The general static parameters are the Name and Node of the Electric Network to which you want to associate the Actor.

- In the Status Variables panel you must specify:
- • Initial Energy Credit: Difference in MWh between the maximum amount of energy that can be imported into the contract minus the energy actually imported at the beginning of the simulation.
- • Number of Discretizations: Number of discretization points of the state variable considered for Optimization..

11.3. Dynamic parameters.

The dynamic parameters of the Actor are created/edited using the following form:



11.4. State Variables, Control and Restrictions.

In the panel "Technical parameters" you must specify:

• Maximum import energy: Maximum amount of energy in MWh that the Actor can import in this mode.

• Maximum import power: Maximum power in MW that the Actor can import.

• Variable import cost: Cost in USD / MWh associated with possible charges for tolls and other possible charges associated with importation.

• Import performance: Losses in p.u. associated with the importation of energy.

• Import availability factor: Availability factor in p.u. which determines the percentage of time that the Actor is available (outside the scheduled maintenance windows) when it is in the import phase.

• Increase factor: It is the factor in p.u. which multiplies the imported energy. Imported energy must be returned multiplied by the increment factor.

• Maximum export power: Maximum power in MW that the Actor can export.

• Variable export cost: Cost in USD / MWh associated with possible charges for tolls and other possible charges associated with export.

• Export performance: Losses in p.u. associated with the export of energy.

• Variable return cost: Variable cost or penalty in USD / MWh that is applied to energy that has not been returned when the return period ends.

• Export availability factor: Availability factor in p.u. which determines the percentage of time that the Actor is available (outside the scheduled maintenance windows) when it is in the export phase.

In the "Windows for exchange" panel you must specify:

- Import start / end date: Time window in which the Actor can import energy.
- Return start / end date: Time window in which the Actor can export or return the imported energy.

11.5. Variables published for SimRes.

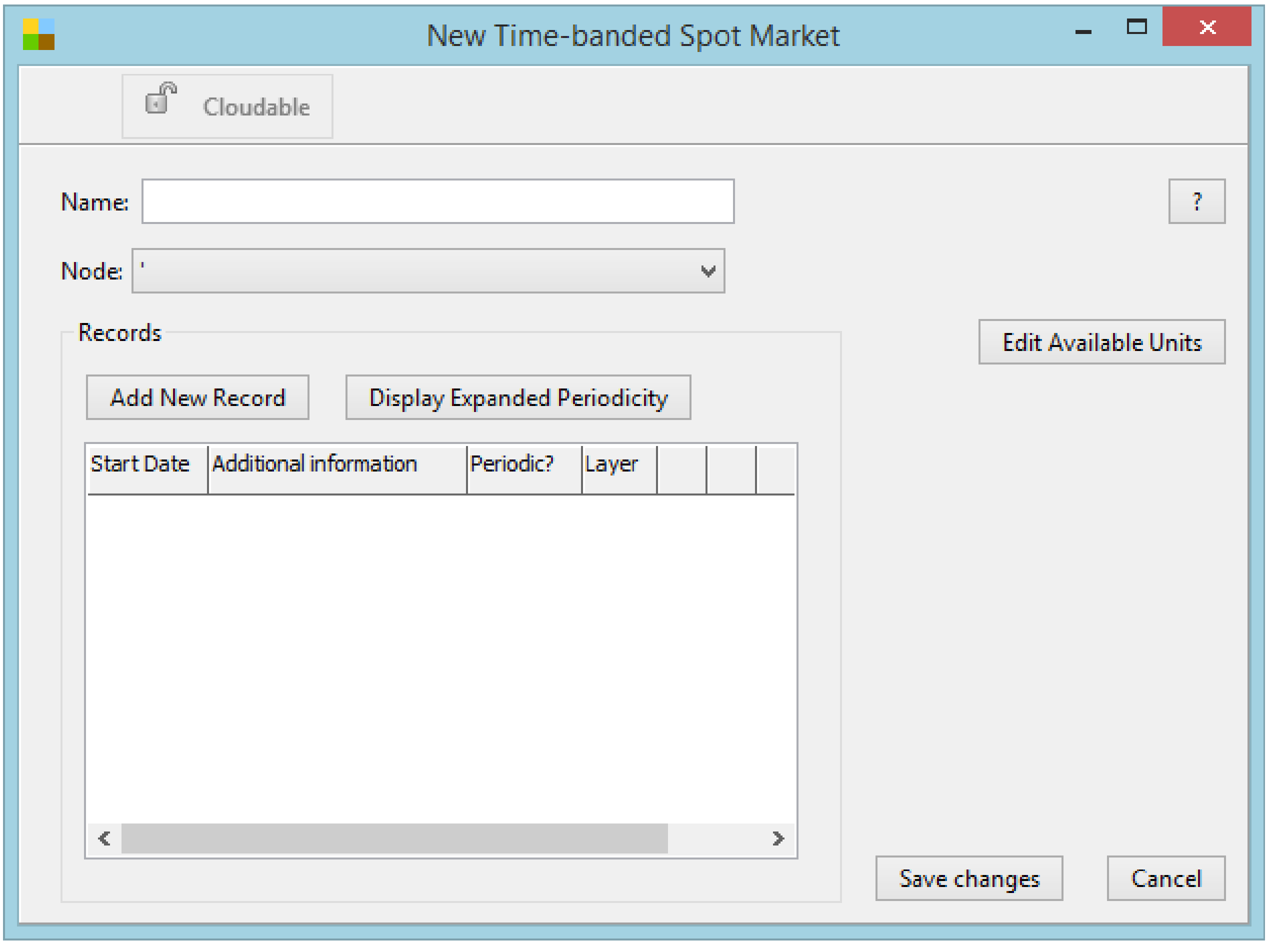
Nombre	***Unidades***	***Poste de tiempo***	***SR3***	***Descripción***
cdp	USD	No	Si	Costs incurred for power generation.
IngresoPorDisponibilidad	USD	No	Si	Payments received by the actor for availability.
IngresoPorEnergía	USD	No	Si	Additional payments received by the actor for the energy dispatched.
P	MW	Si	Si	Power injected to the node.
ReservaRotante	MW	No	No	Rotating Reserve
cv_Spot	USD/MWh	No	No	Spot variable cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the power limits constraint.
ParticipacionSCS	USD	No	No	Participation in the System Reliability Service.
ForzamientoSCS	USD	No	No	Forcing in the System Reliability Service.
cv	USD/MWh	No	No	Resulting variable cost for the Actor dispatch.
E_Credito	MWh	No	No	Energy Credit available for import.
fase	[0,3]	No	No	Phase in which the Actor is. 1 = Import; 2 = Return; 3 = Last Step Return; 0 = Inert.
dE_Credito	MWh	No	No	Energy credit earned or lost during the time-step
Disponible	1 o 0	No	No	Availability of the Actor to import or export energy: 1 = "Available", 0 = "Unavailable".

11.6. Time-banded Spot Market.

The Time-banded Spot Market is an Actor that belongs to the International and Others Group. This Actor can deliver (import) or withdraw (export) energy from the Node to which it is connected with different prices and powers specified for each time post.

11.6.a) Operation description.

The registration form of the Time-banded Spot Market is presented below:



For each time-band, a source of market prices and a range of exchange powers with the network connection Node must be specified. In the case where it is fulfilled that the price of energy in the connection Node is higher than the price of the Source, the energy available in the Node is imported and otherwise exported. Additionally, the Actor makes it possible to model protection mechanisms for markets due to marginal cost caps.

The general features of the Actor are described in the document General Characteristics of the Actors.

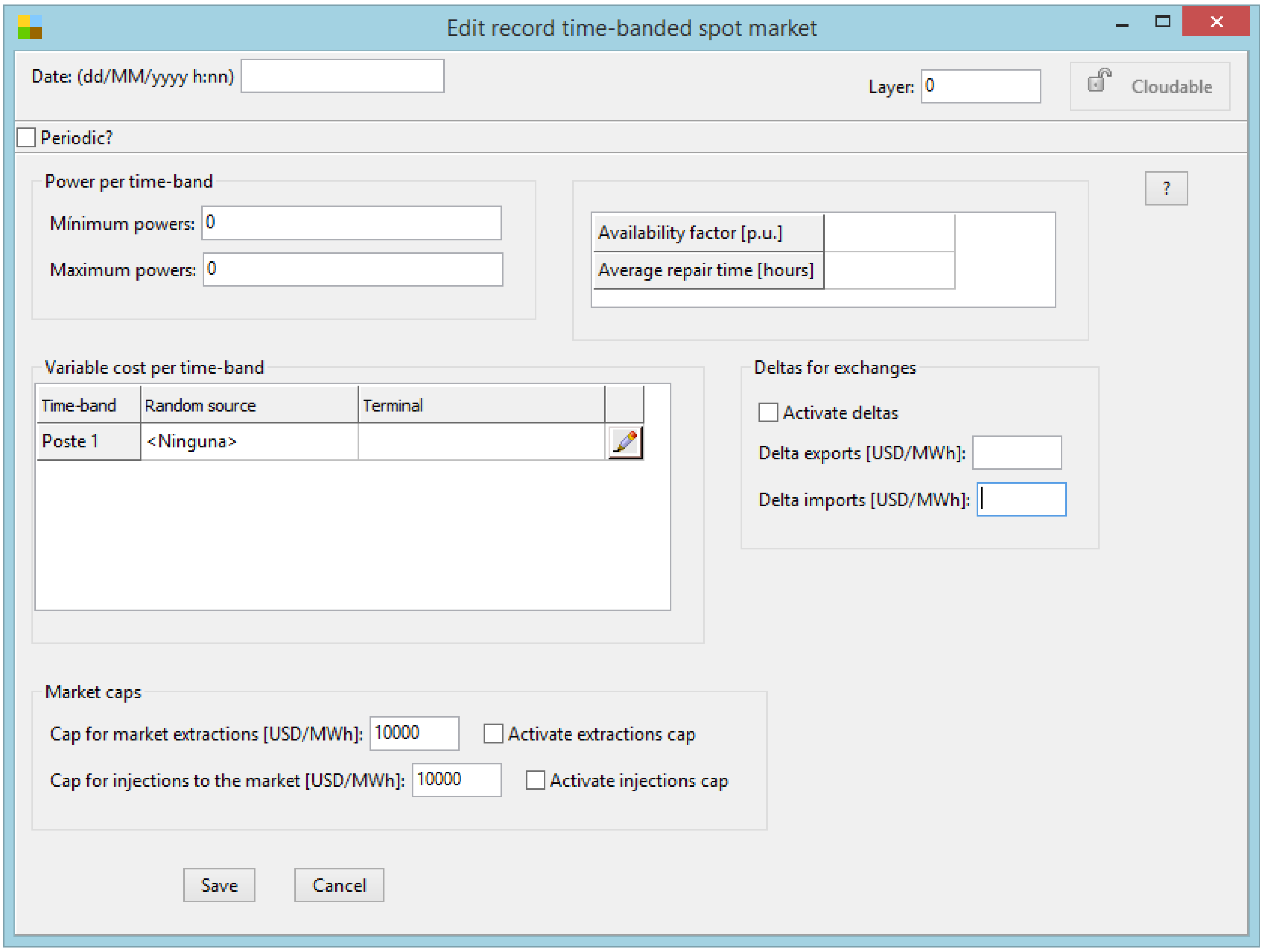
11.6.b) *Static parameters.*

The static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

11.6.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- Minimum Powers: It is the minimum (negative) value of power in MW that the actor can exchange with the node to which it is connected. It must be less than or equal to zero so that the actor can withdraw (export) energy from the node to which it is connected. The absolute value of Pmin is therefore the maximum power that the node can export to the market.
- Maximum Powers: It is the maximum (positive) value of power in MW that the actor can exchange with the node to which it is connected. It must be greater than or equal to zero so that the actor can inject energy to the node to which it is connected. The Pmax value is therefore the maximum power that the node can import from the market.

In the "Variable costs per time-band" panel you must specify:

- Variable costs table by post: A random source and terminal must be entered to model the market price in USD / MWh of each time post.

In the "Market Caps" panel you must specify:

- Cap for market extractions: Maximum price in USD/MWh at which you are willing to export the market to the network connection node. If the market price is higher than the limit of extractions, the maximum exchange power is canceled. In order for this mechanism to be active, check the box "Activate extractions cap". This parameter has the task of modeling mechanisms to protect export markets due to marginal cost caps, since it would not be reasonable for a country to export energy at risk of rationing.
- Cap for injections to the market: Maximum price in USD / MWh at which the network connection node is willing to export to the market. If the price of the Spot Market is higher than the cap for injections, the value of the cap is lowered so that the market is not willing to pay more than that value. For this mechanism to be active, check the box "Activate injections cap". This parameter is a node defense mechanism to prevent energy from being extracted from the node to the market in situations of high node costs.
- In order to avoid inconsistencies, it must be fulfilled that Cap for market extractions ≤ Cap for injections to the market.
- It is noted that if "Activate injections cap" is marked, "Activate extractions cap" must also be marked.

In the "Deltas for exchanges" panel you must specify:

- Delta exports: Value in USD/MWh that must exceed the difference between the variable cost of the Market and the marginal cost of the node for the export (energy flow from the node to the market) to happen.
- Delta imports: Value in USD/MWh that must exceed the difference between the marginal cost of the node and the variable cost of the Market so that the import (which flows from the Market to the node) happens.

- To activate the Deltas for exchanges, check the box “Activate deltas”.

General parameters:

- Availability Factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.

- Average Repair Time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.

11.6.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Costs incurred for power generation. If the DeltaExchanges are activated, if P > 0 (that is, the Market injects energy to the node to which it is connected), the cost is computed as the energy valued at the variable cost of the market plus the Import delta. If P < 0 (that is, the Market withdraws energy from the node to which it is connected), the cost is computed (it is negative because it is an income) as the Energy multiplied by the marginal cost of the node plus the Exporter delta.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
Cost	USD	Yes	Yes	Total cost incurred by the actor due to the exchange of energy with the network connection node. Corresponds to the cdp but opened by Post.
cv	USD/MWh	No	Yes	Spot Market Price
NAvailableUnits	u	No	Yes	Number of available units in the time post.
otherMarket_BenefitImpo	USD	Yes	Yes	Economic benefit of the node for exports to the Market. It is the energy multiplied by the difference between the variable cost of the market and the price of the exchange. The exchange price is calculated as the marginal cost of the node plus the Exporter Delta.
otherMarket_BenefitExpo	USD	Yes	Yes	Economic benefit of the Market for exports to the node. It is the energy (delivered to the node) multiplied by the Import Delta.

11.6.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 2 Control Variables:

- $Pi_{Node-Market}$: Power injected by the Node to the Market.
- $Pi_{Market-Node}$: Power delivered by the Market to the Node.

The Actor adds the following restrictions to the optimization problem:

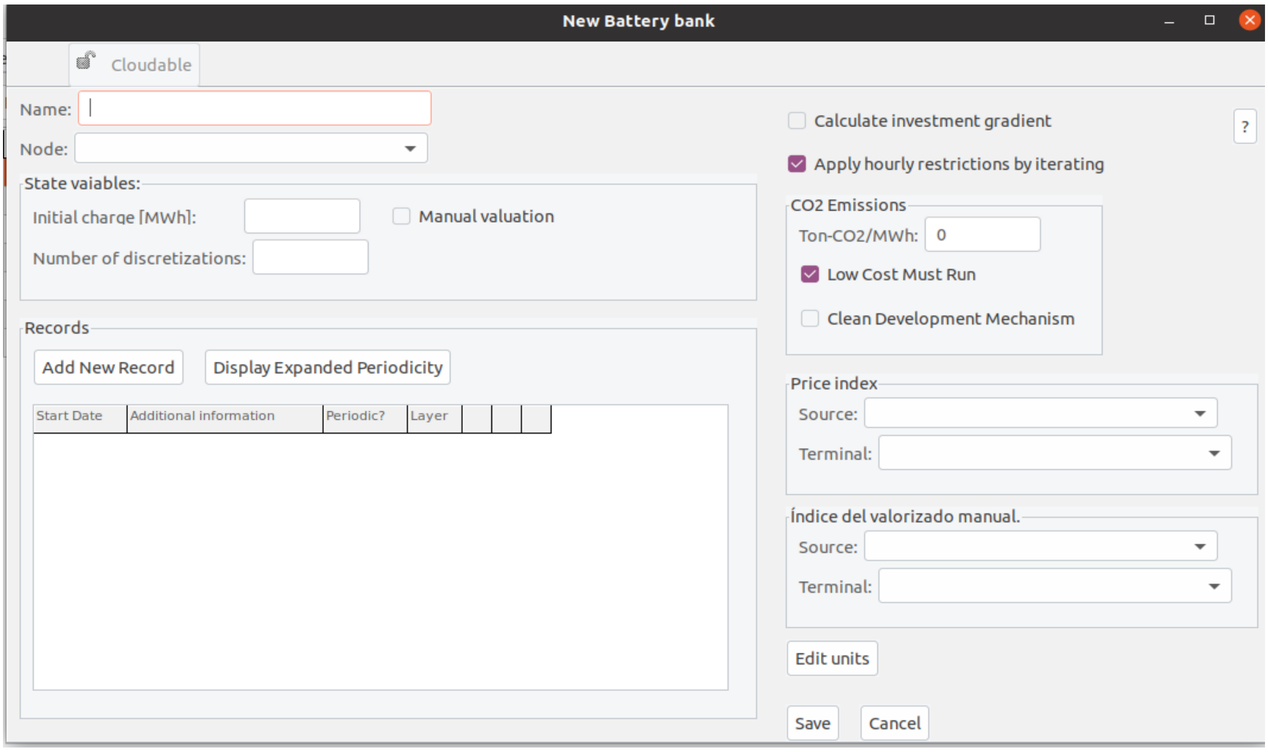
- Node power restriction.

11.7. Battery Bank

The Battery Bank is an Actor that belongs to the International Group and Others. This Actor was created to model microgeneration systems with battery banks. This type of actor can demand energy from the Network (grid), store the energy and later on deliver the stored energy to the grid.

11.7.a) Operation description.

The registration form of the Battery Bank is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

11.7.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network with which you want to associate the Actor.

In the “State Variables” panel you must specify:

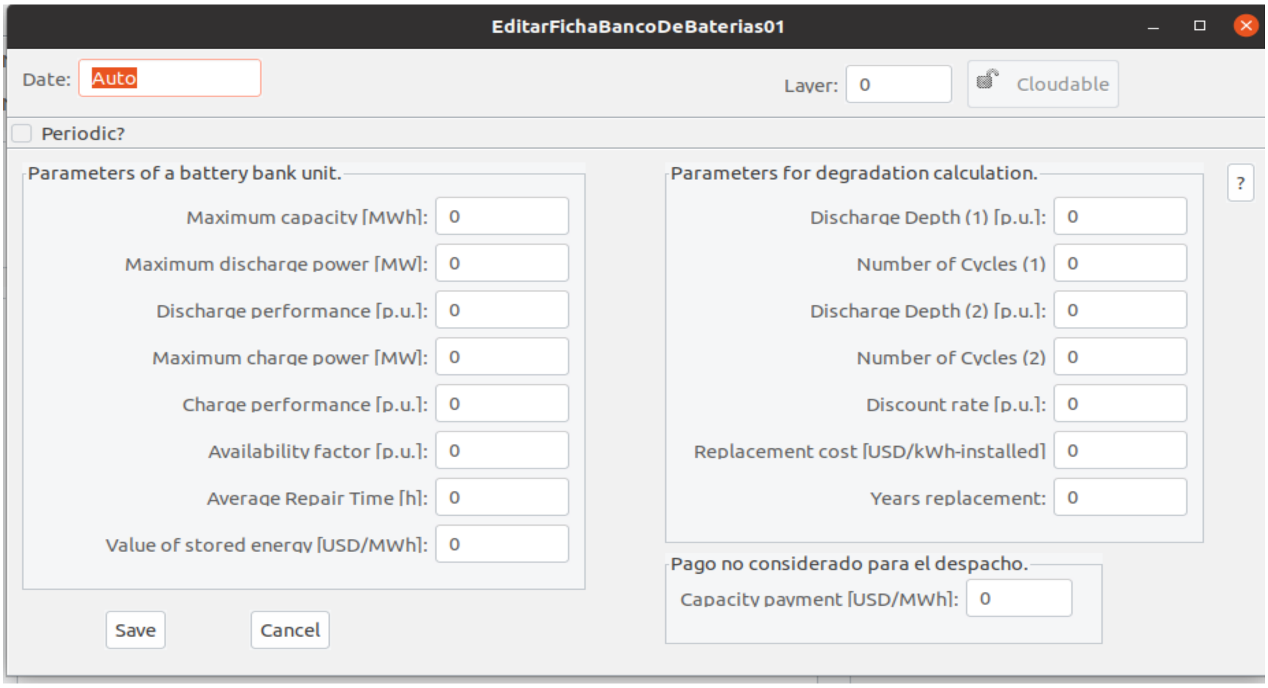
- Initial charge: Energy stored in the Battery Bank in MWh at the start of the simulation.

- Number of discretizations: Number of discretizations of the state variable (Stored Energy).
- Manual valuation: If this box is checked, the value in USD/MWh of the energy stored in the battery must be set in the dynamic parameter Records. Otherwise, the stored energy value is obtained from optimization.
- Price index:Indexes the replacement cost specified in the dynamic parameters. Thus, it allows to consider variations in the price of the technology.
- Manually valuation index: Indexes the value of the stored energy specified in the dynamic parameters.

11.7.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

In the “Parameters of a battery bank unit” panel

- Maximum Capacity (*CapMax*): Maximum energy in MWh that the battery can store.
- Maximum discharge power: Maximum power in MW that the battery bank can inject into the network.
- Discharge performance: Performance in p.u. of the battery when injecting power to the network.
- Maximum charge power: Maximum power in MW that the Battery Bank can extract from the network.
- Charge performance: Performance in p.u. of the battery when extracting power from the network.
- Availability factor: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- Average repair time: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- Value of stored energy: Value imposed on the energy stored in the battery in USD/MWh if the “Manual valuation” box is checked. If this box is not checked, the stored energy value is obtained from the optimization.

In the “Parameter for degradation calculation” panel you must specify:

- Depth of discharge (1): Depth of discharge of the Battery in p.u. of the total capacity during the first cycling test.
- Numbers of cycles: Number of cycles of the first cycling test.
- Depth of discharge (2): Depth of discharge of the Battery in p.u. of the total capacity during the second cycling test.
- Numbers of cycles (2): Number of cycles of the second cycling test.
- Discount rate: Discount rate in p.u. considered for the replacement of the battery.
- Replacement cost: Cost in USD/kW-installed considered for the replacement of the Batteries due to their degradation.
- Replacement years: Number of years considered for the replacement of the Battery.

11.7.d) Published variables for SimRes.

The Actor allows to publish the following variables:

Name	***Unit***	***Time post***	***SR3***	***Description***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
PGen	MW	Si	No	Power injected to the connection node.
PDem	MW	Si	No	Power extracted from the connection node.
cv_MWh	USD/MWh	No	No	Value of the energy stored in the battery.
X_Charge	MWh	No	No	Energy stored in the battery
NAvailableUnits	u	No	Yes	Number of available units in the time-band.
cfrefillUSD_MWh_installed_By_Pass_T	USD	No	No	missing
cvDegDem	USD/MWh	No	No	Variable cost due to battery degradation according to demand.
cvDegGen	USD/MWh	No	No	Variable cost due to battery degradation, acting as a Generator.

11.7.e) State variables, Control and Restrictions.

The Actor add 1 State Variable to the system:

- X_{Carga} : Energy stored in the battery bank per time step.

The Actor adds 2 Control Variables per time-band i :

- P_{iGen} : Power injected into the connection node.
- P_{iDem} : Power extracted .

The Actor adds the following restrictions to the optimization problem:

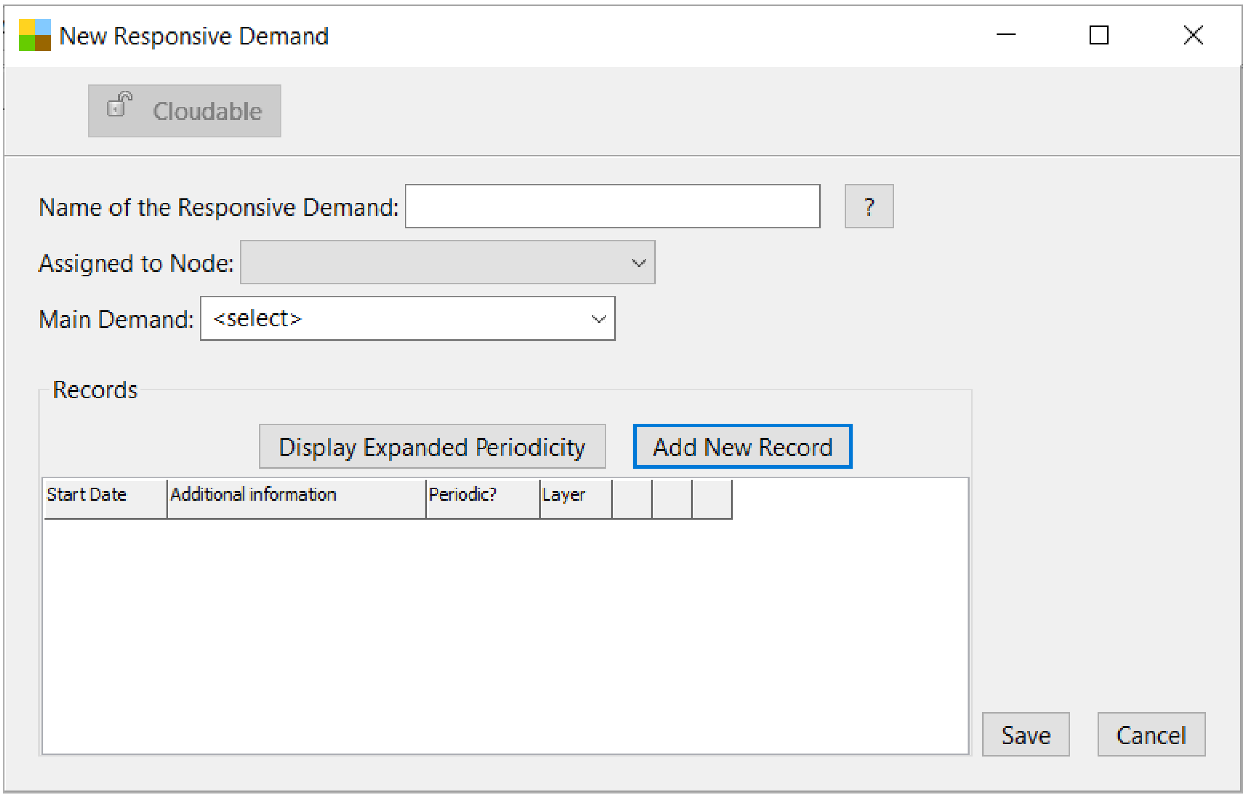
- Node power restriction.

12. Responsive Demand.

The Responsive Demand is an Actor that belongs to the International and Others Group. This Actor allows the shifting or management of the demand between the different time posts with the objective of maximizing the economic benefit. A base demand, the percentage that can be manageable of that demand and the utility obtained by the power demanded in each time post must specified. The energy demanded does not vary due to the inclusion of this actor, the Actor modifies its distribution in the different posts of the time step. The Responsive Demand is distributed among the different time posts depending on (or in response to) the generation costs and utilities obtained.

12.1. Operation description.

The registration form of the Responsive Demand is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

12.2. Static parameters.

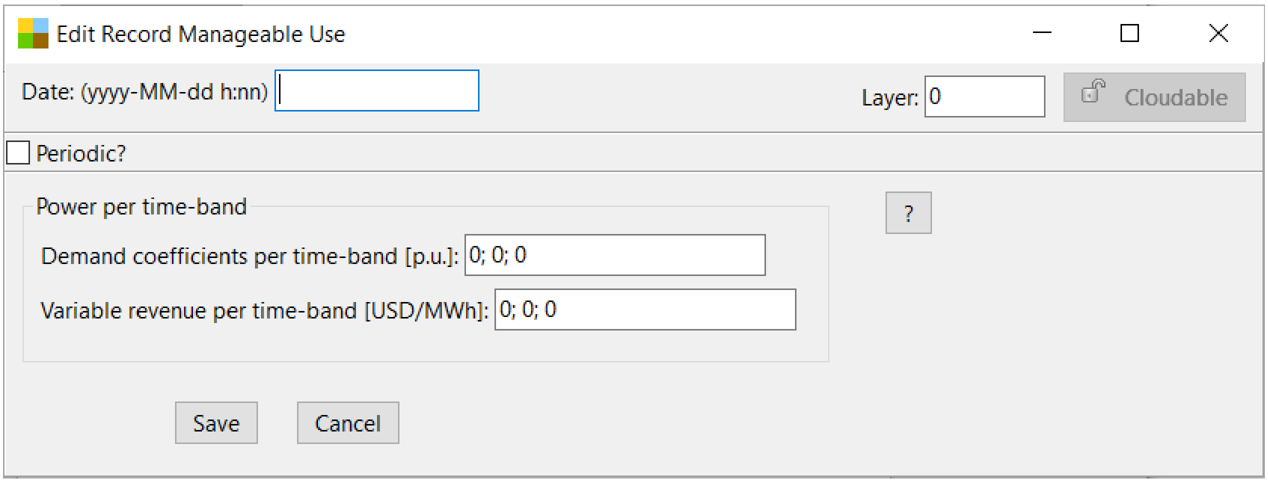
The general static parameters are the Generator Name and Node of the Electric Network with which you want to associate the Actor.

In the “Main Demand” combobox, it must be selected the base demand that will be considered to carry out the demand management.

12.3. Dynamic parameters.

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



In the “Power per time-band” panel it must be specified:

- Demand coefficients per time-band: Percentage of the Main Demand that can be managed in each time post. The values entered must be separated by “;”.
- Variable revenue per time-band: Revenues in USD/MWh that the Actor obtains for demanding each MWh in each of the time posts. The values entered must be separated by “;”.

12.4. Published variables for SimRes.

The Actor allows to publish the following variables:

Nombre	***Unidades***	***Poste de tiempo***	***SR3***	***Descripción***
cdp	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
P	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
Forcing SCS	USD	No	No	Forcing in the System Reliability Service.
DirectRevenuesOfStep	USD	No	No	Revenues of the demanded power, valued according to the revenues of each post.
pdpp	MW	Si	No	Power demanded by the Actor according to the optimal dispatch.
pgpp	MW	Si	No	Manageable power demand.

12.5. State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds 1 Control Variables:

- P_i : Power extracted from the Node in the time post i.

The Actor adds the following restrictions to the optimization problem:

- Node power restriction.
- Energy balance in the time step: $\sum_{i=1}^{NPosts} P_i . DurPos_i = \sum_{i=1}^{NPosts} Dem_i . fdpp_i . DurPos_i$. Being $DurPos_i$ the duration of the time post i, Dem_i the demand and $fdpp_i$ the percentage of the Main Demand that can be managed in the time post i.

13. Fuel supply network and Actors.

TCombustible

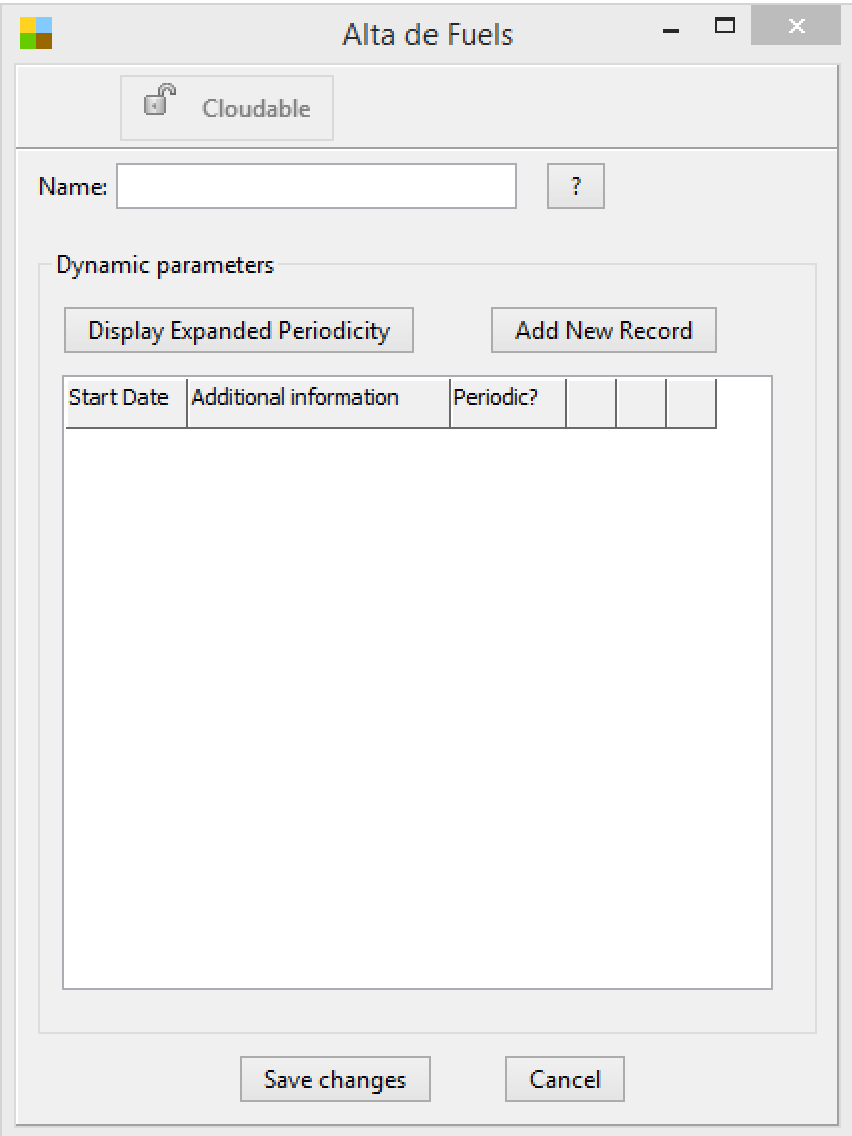
TNodoCombustible
TArcoCombustible
TSuministroSimpleCombustible
TRegasificadora
TDemandaCombustibleAnioBaseEIndices
TGSimple_BiCombustible
TGSimple_MonoCombustible
TGTer_combinado_horario

13.1. Fuel.

Fuel is an independent Entity that is used to build a Fuel Network. To define a fuel network, you must first specify which are the different fuels that you want to model and then the Actors that interact in it

13.1.a) Operation description.

The registration form of the Fuel Entity is presented below:



The Entity has the general functionalities of the Actors, which are described in the document General Characteristics of the Actors.

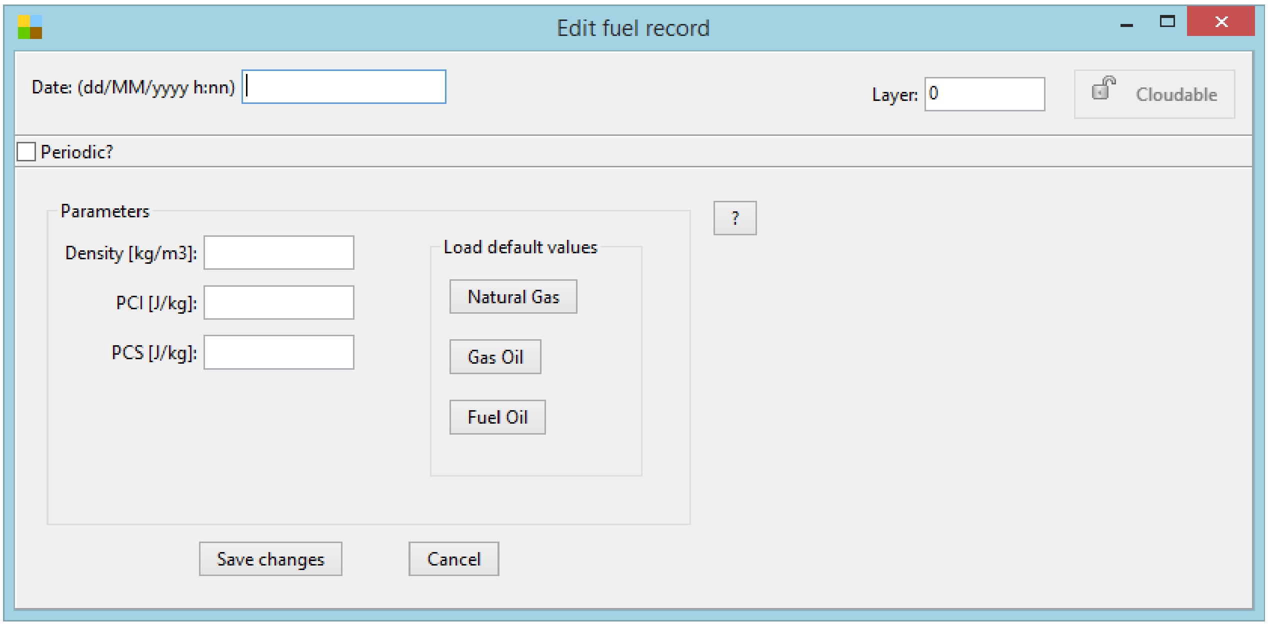
13.1.b) Static parameters

The only static parameter is the Name of the Fuel.

13.1.c) Dynamic parameters.

The dynamic parameters of the Entity are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Entity must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- Density: Fuel density in kg/m³.
- PCI: Lower Calorific Power in J/kg.
- PCS: Higher calorific power in J/kg.

Load Default values: allows you to load the default values of the most common fuels (Natural Gas, Gas Oil and Fuel Oil).

13.1.d) Published variables for SimRes.

The Entity does not publish variables in the SimRes.

13.1.e) State variables, Control and Restrictions.

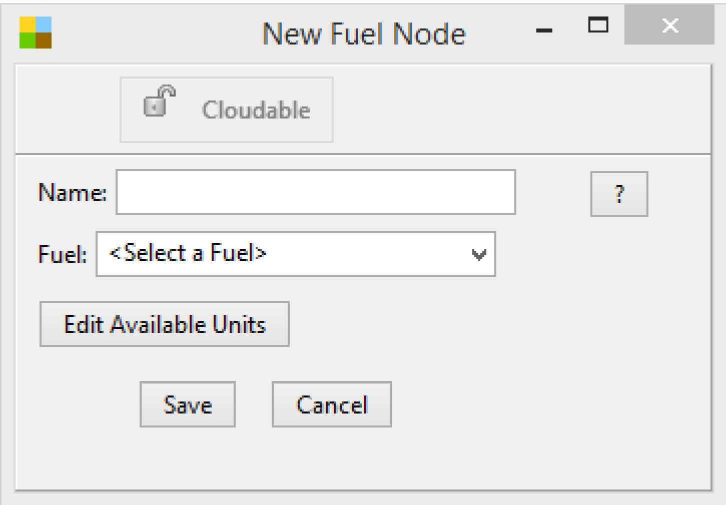
The Entity does not introduce State Variables, nor control nor restrictions to the optimization problem.

13.2. Fuel Node.

The Fuel Node is an Actor belonging to the Fuel Network. The Actor represents a connection point to supply or consume fuel.

13.2.a) Operation description.

The registration form of the Fuel Node is presented below:



It must specify the Name and Fuel that can be supplied or consumed (the drop-down list allows you to choose between the Fuel Elements previously defined in the Fuel tab). The Actor has a Records panel along with the rest of the general functionalities of the Actors, which are described in the document General Characteristics of the Actors.

13.2.b) *Static parameters.*

The static parameters are the Name and the associated Fuel, previously created.

13.2.c) *Dynamic parameters.*

The Actor has no dynamic parameters, since its parameters do not vary during simulation.

13.2.d) Published variables for SimRes.

The Actor does not publish variables in the SimRes.

13.2.e) State variables, Control and Restrictions.

The Actor does not introduce State Variables, nor control Variables to the optimization problem.

The Actor introduces an equality restriction to be respected in each time post k . It must be instantly fulfilled that the fuel inlet and outlet balance is zero.

$$\sum_{i=1}^{i=N} S_i - \sum_{j=1}^{j=M} D_j = 0$$

ec.1 Balance in the Fuel Node in each time post k .

Where:

S_i : Fuel i supply to the Fuel Node.

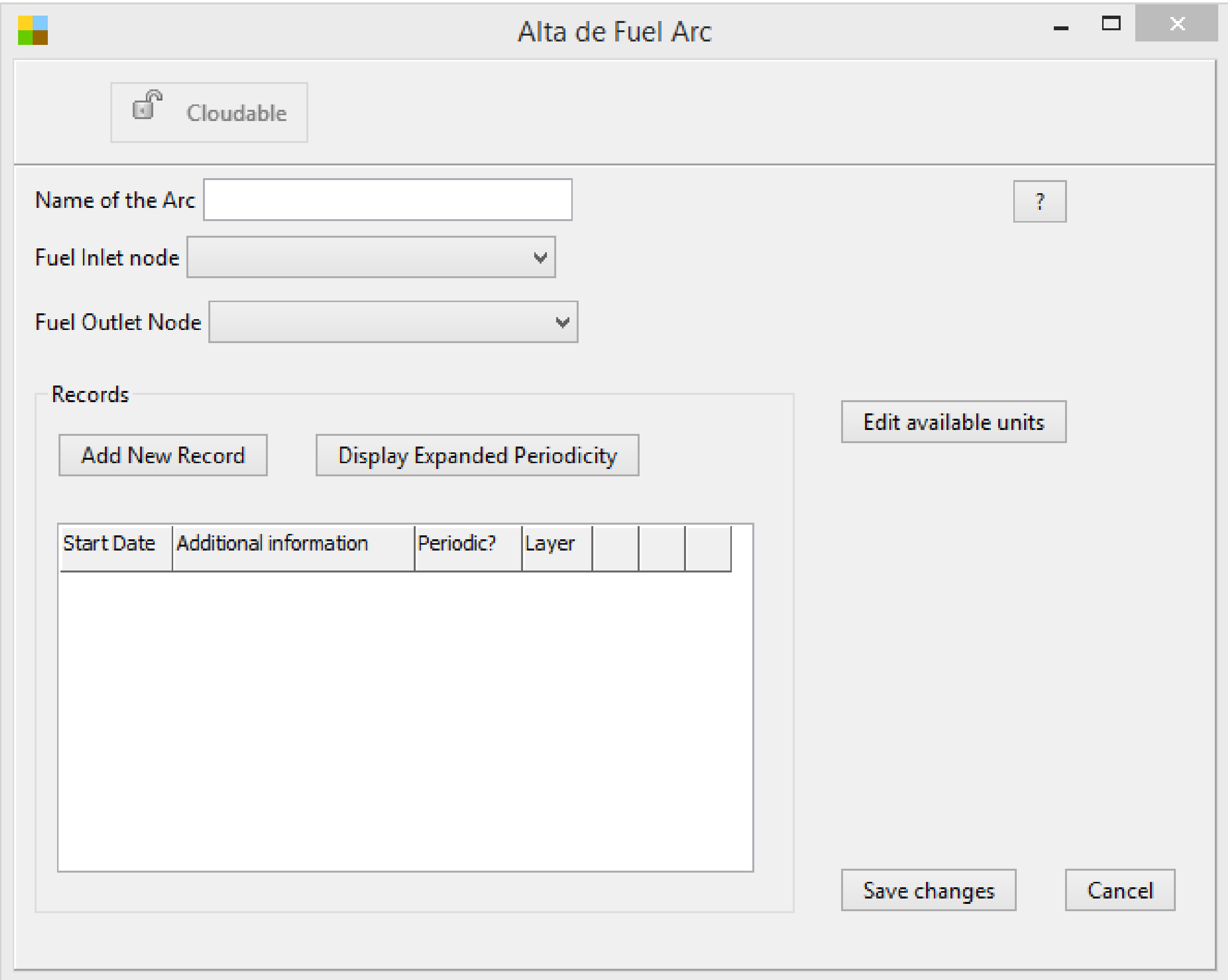
D_j : Fuel j consumption of the Fuel Node.

13.3. Fuel Arc.

The Fuel Arc is an Actor belonging to the Fuel Network. The Actor's function is to make the connections between two Fuel Nodes of the system and thus allow the flow of fuel between them. The fuel transport network is modeled from Fuel Nodes and Fuel Arcs, defining possible capacity and availability restrictions in the Arcs.

13.3.a) Operation description.

The registration form of the Fuel Arc is presented below:



It must specify the Name of the Arc, the inlet Fuel Node and the outlet Fuel Node. The Actor has a Records panel along with the rest of the general functionalities of the Actors, which are described in the document General Characteristics of the Actors.

To indicate the direction of the fuel flow, in each Fuel Arc it is mandatory to load the information of the Fuel Inlet Node and the Fuel Outlet Node. In the case where you want to model a two-way fuel flow, it is necessary to create two independent Fuel Arcs by swapping the Fuel Node in and out.

Fuel Arcs can only connect two Fuel Nodes of the same type. This means that if a Fuel Node has a fuel A associated, it can only be connected through a Fuel Arc with another Fuel Node that has the same fuel A.

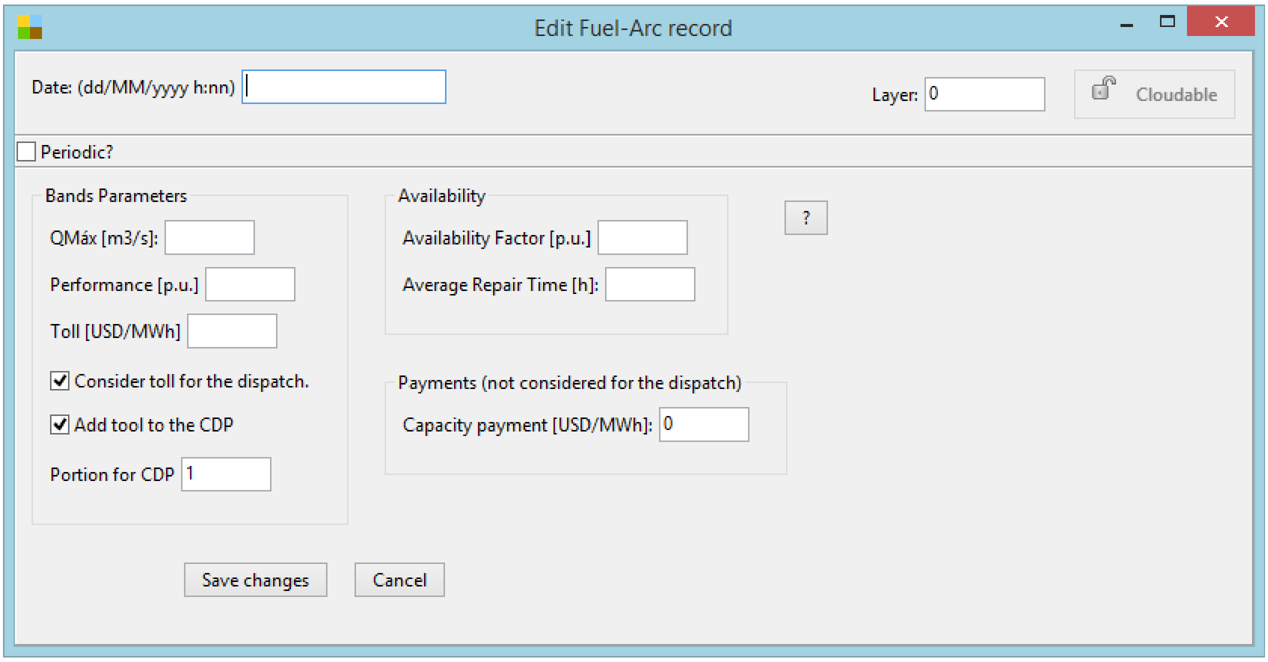
13.3.b) *Static parameters.*

The static parameters are the Name, the inlet Fuel Node and the outlet Fuel Node.

13.3.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- QMax: It is the maximum fuel flow rate in m^3/s that the Actor can transport between the fuel inlets and outlets.
- Performance: These are the losses of the transport system in p.u. It is represented as a factor that multiplied by the fuel inlet flow to the Fuel Arc determines the output fuel flow.

- Toll: It is the toll in USD/m³ for the use of the Fuel Network.

It should also be indicated if it is desired that said toll be considered for the dispatch and if it is desired that it be added to the Direct Cost of the Step (CDP). In the case where you want to add, you must specify a factor. By default the checkboxes Consider Toll in the dispatch and Add Toll to the CDP are active and the Factor for CDP in 1.

- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows..
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.

13.3.d) Published variables for SimRes.

The Actor allows to publish the following variables per time post:

Name	***Unit***	***Time post***	***SR3***	***Description***
Direct Cost of the Step	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
QMax	m3/s	Yes	Yes	Maximun Fuel flow.

13.3.e) State variables, Control and Restrictions.

The Actor does not introduce State Variables to the optimization problem.

The Actor adds 1 Control Variable per time post i :

- q_E^i Fuel Flow inlet to the Fuel Arc.

The Actor introduces an equality restriction and two inequality restrictions to be respected in each time post. It must be fulfilled instantly that the balance of fuel inlet and outlet flow is zero, and that the flow rates are limited to Qmax, as shown in Eq. 1.

$$q_E . PST - q_S = 0$$
$$q_E \leqslant QMax$$
$$q_S \leqslant QMax$$

ec.1 Balance on the Fuel Arc in the time pos k .

Where:

q_E : Fuel Flow inlet to the Fuel Arc.

q_S : Fuel Flow from the Fuel Arc output.

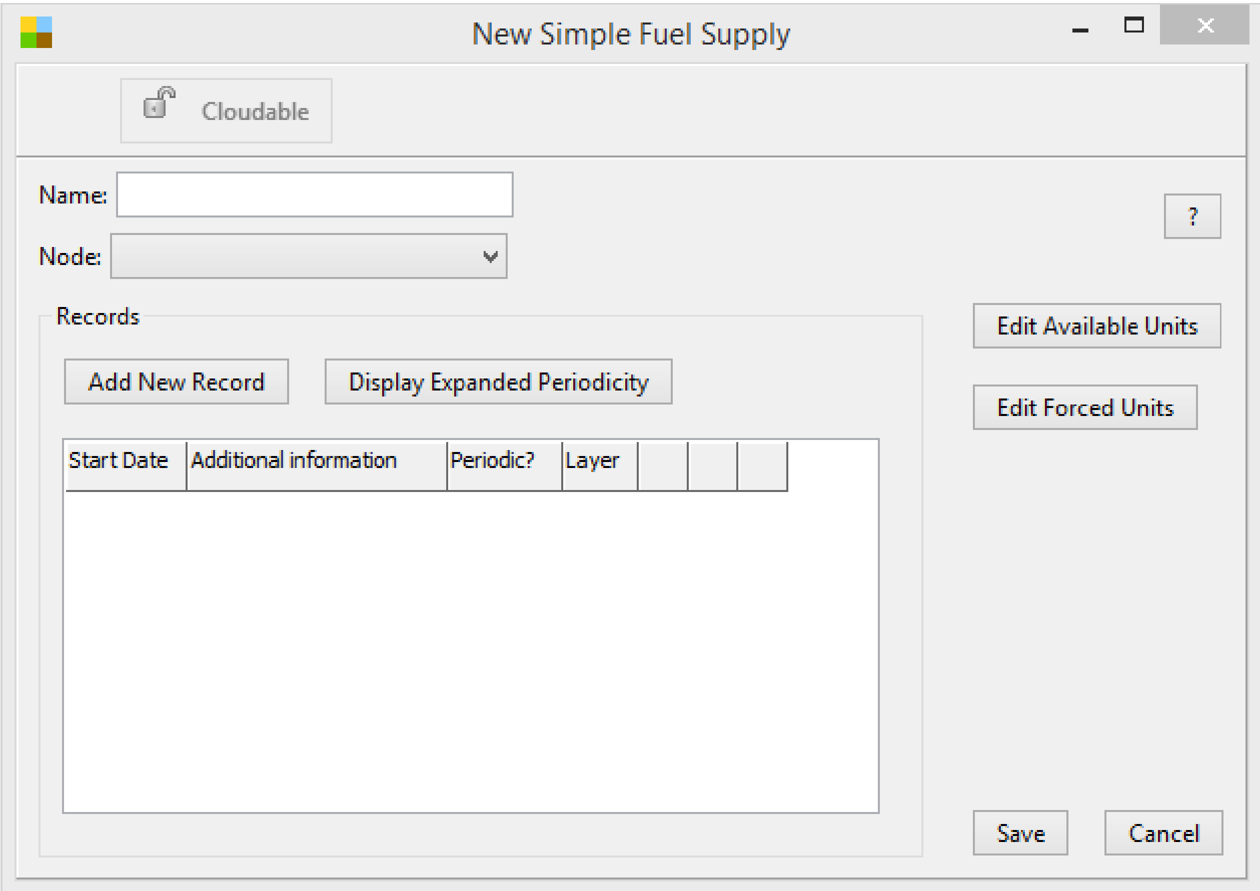
PST : Fuel Arc system transport losses.

13.4. *Simple Fuel Supply.*

The Simple Fuel Supply is an Actor belonging to the Fuel Network. The function of the Actor is to supply the fuel of the type specified to provide the non-electrical demands and the Generators fuel demands. Bi-fuel Generators may have more than one associated supply.

13.4.a) Operation description.

The registration form of the Simple Fuel Supply is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

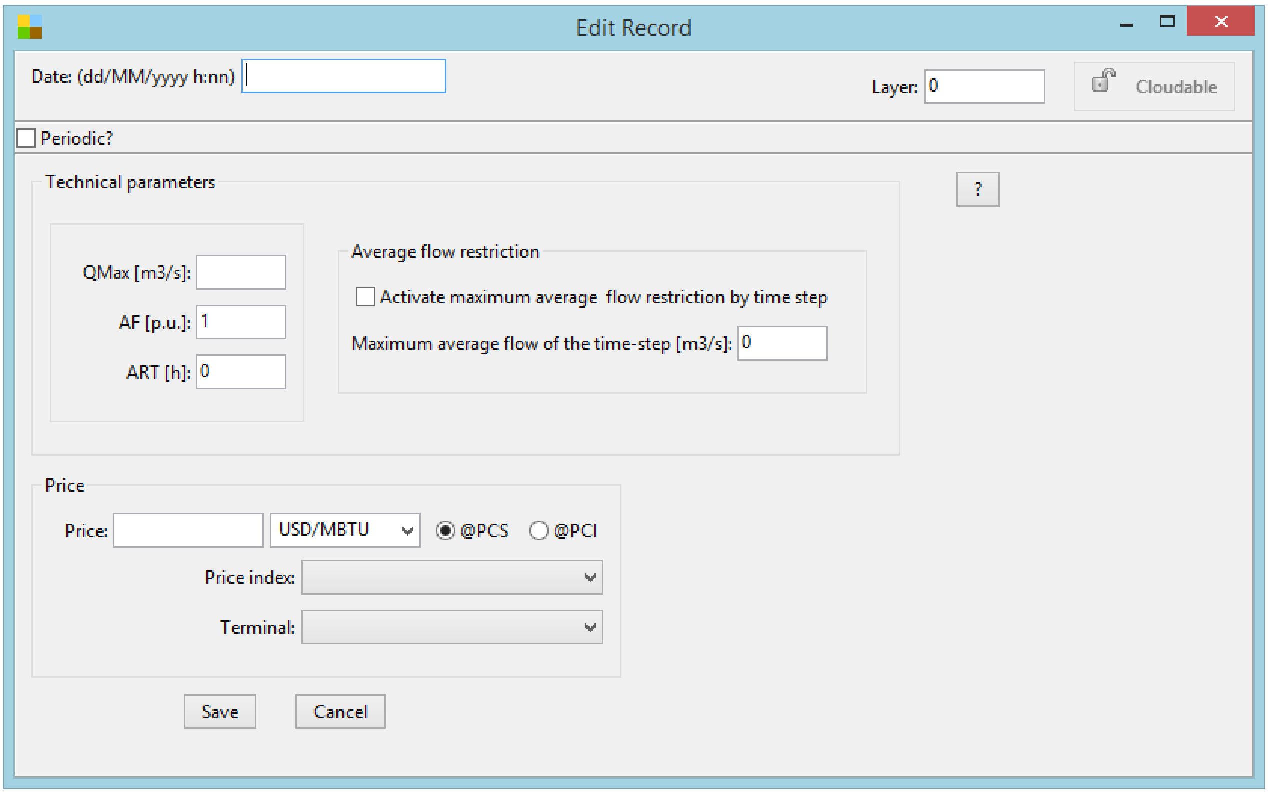
13.4.b) *Static parameters.*

The static parameters are the Name and Fuel Node of the Fuel Network.

13.4.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- QMax : It is the maximum fuel flow in m3/s that the Actor can supply in the fuel Node to which it is connected.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.

- Average flow restriction: A maximum average flow restriction can be activated per time step j, specifying the maximum value of the flow in m^3/s.
- Price: It is the price of fuel by selecting the corresponding unit of measure.

It must be specified if said price is a Higher or Lower Calorific Power (PCS or PCI). It is possible to index the fuel price to a previously created source by selecting it in the Price Index and Source combobox.

13.4.d) Published variables for SimRes.

The Actor allows to publish the following variables per time post:

Name	***Unit***	***Time post***	***SR3***	***Description***
Direct Cost of the Step	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
QMax	m3/s	Yes	Yes	Maximun Fuel flow.
QAvMax	m3/s	Sí	Sí	Maximum average fuel flow per time step.

13.4.e) State variables, Control and Restrictions.

The Actor does not introduce State, nor Control Variables to the optimization problem.

The Actor introduces two inequality restrictions to be respected, one in each time post i and the other in each time step j, as shown in ec.1. It must be fulfilled that the supply flow is limited to $QMax$ at each time post i. If the Medium Flow Restriction is activated, another restriction appears that limits the average flow to $QMax_{average}$ at each time step j.

$$q \leqslant QMax$$
$$q_{average} \leqslant QMax_{average}$$

ec.1 Time post and time step restrictiones.

Dónde:

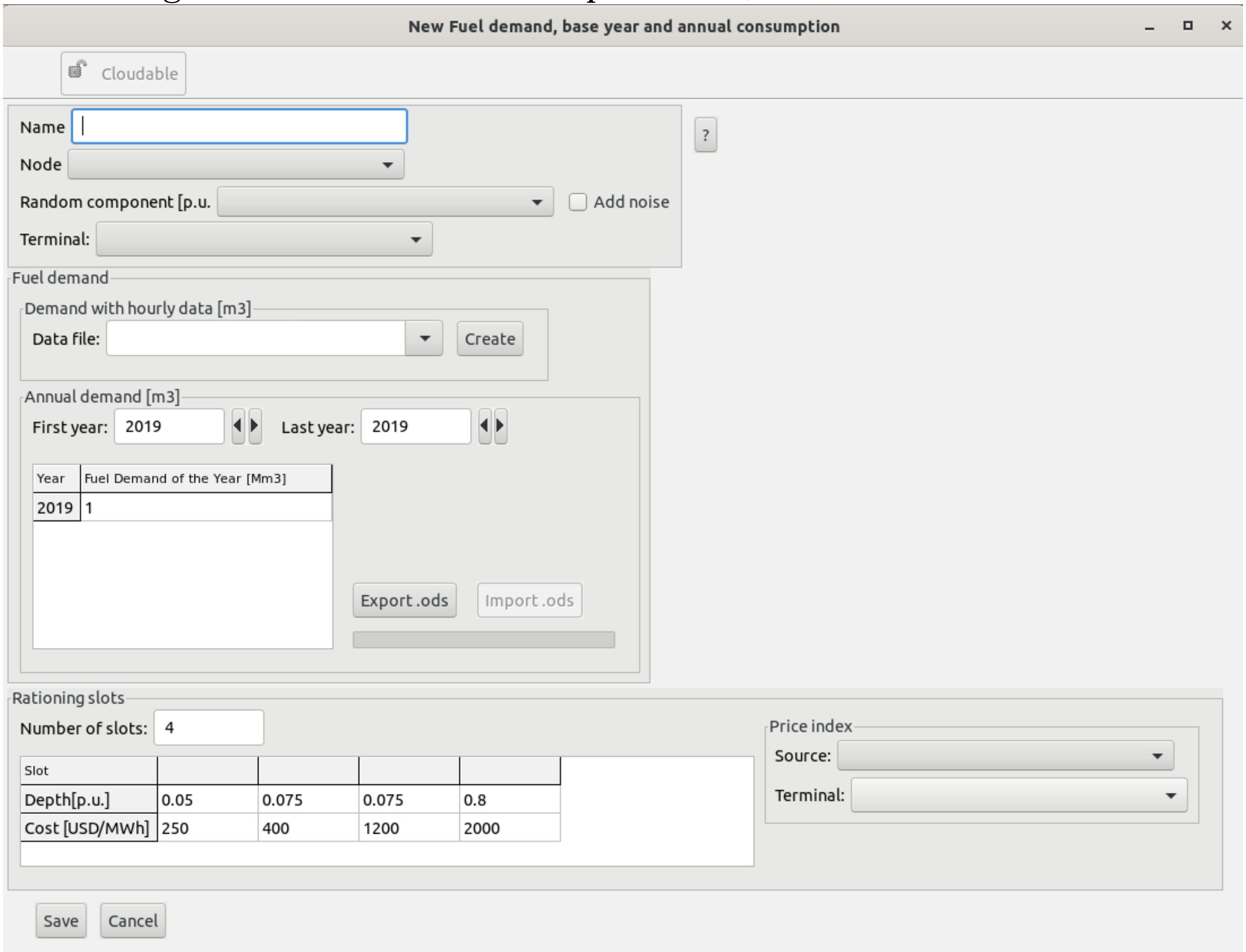
q : Supply fuel flow in time post i .

$q_{average}$: Average supply fuel flow in time step j .

13.5. Fuel Demand, base year and annual consumption.

The Fuel Demand is an Actor belonging to the Fuel Network. The Actor's role is to model the consumption of unused fuel for electric power generation (non-electric demand).

El siguiete formulario se utiliza para crear/editar un Actor:



It must specify the Name and Fuel Node of the Fuel Network. To be able to create this actor, it is necessary to have a binary file of the base year that has the information of the demand for non-electric fuel detailed on an hourly basis, and based on it specify the total annual fuel consumption for all the years that are Consider in the study.

13.5.a) Static parameters.

Within the static parameters of the Actor, you must specify the Name and a Fuel Node to which you want to associate the Fuel Demand.

n the Random Component (p.u. of Demand) and associated Terminal selectors, you can assign a random source that represents the variations in demand around a preset value. The random source must generate the noise in p.u. Of demand. The value used in each time step will be the deterministic value multiplied by (1+ r) where r is the value read from the source. In the case in which it is not desired to use random sources, the option “None” must be specified in the box and the multiplier in this case is 1.

13.5.a.i Fuel Demand Specifications:

To create the binary demand with hourly data, you must select the Data File (binary file with extension “.bin”) with the fuel demand information of the base year or create a new one using te “Create” button.

To define the annual demand, you must indicate, in the First Year and Last Year boxes, the first and last year of fuel demand data that you want to consider in the study. From the above, the fuel demand for the year is entered in the table below for each year of the specified period.

For each year of the study, the base file data is scaled hourly so that the resulting consumption (annual fuel demand) matches that specified in the table. Care should be taken that the period considered (time interval between the First Year and the Last Year) covers the time horizon that was specified to make the optimization.

Finally, there is the Export .ods button that opens a form where you export the values of the table. In this way it is possible to modify the data and then with the Import .ods button you can load the modified data into the table.

13.5.a.ii Rationing slots:

In an analogous way to the electrical system, when it is not possible to meet the fuel demand, it is said that there is a failure in the fuel supply. For this, the Failure Stlots (or steps) are created with their associated costs. When the fuel deficit situation arises, they enter service to meet the Node Fuel Demand. The dispatch of these fault machines are indicators of the system deficit and the amount of fuel involved. It must be fulfilled that the sum of the depths of the failure steps must always be equal to 1 in order to ensure that the Fuel Demand is met at all times.

It is allowed to specify the number of failure steps to consider, their depth and cost. The Price Index (Source and Terminal selectors) allows you to select a Source to index the failure costs. This is useful because in long-term Payrooms in which fuels have indexation, it is reasonable to index the failure costs so that the system resources do not end up being more expensive than the failure costs.

13.5.b) Dynamic parameters.

The Actor has no dynamic parameters, since its parameters do not vary during simulation.

13.5.c) Variables published for SimRes.

Nombre	***Unidades***	***Poste de tiempo***	***SR3***	***Descripción***
CostoDirectoDelPaso	USD	No	yes	Sum of the direct costs incurred in each time post.
C	MW	yes	yesí	Fuel flow extracted from the Fuel Node..
CF_j	MW	yes	yesí	Fuel Failure Flow extracted from the Fuel Node for the failure slot j during the time-band i of the simlation time-step.
CostoFalla_j	USD	yes	yesí	Cost of failure incurred in the failure-slot j during the time-band i .

13.5.d) Variables Status, Control and Restrictions.

The Actor does not introduce State Variables to the optimization problem.

The Actor introduces the following Control Variables:

For each Failure Step f a Control Variable $C^i_{Failure}$ is entered for ecah Time-Band i . This variable is the fault fuel required to be dispatched and depends on the Depth of the fault in the Time Post being considered. As an example: for 20 fault steps and 5 Posts, 20 Control Variables are totaled.

The Actor introduces the following Restrictions on Control Variables:

Para cada Variable de Control $C^i_{Failure}$ se impone una restricción que representa el máximo valor que puede tomar dicha variable para cada Escalón de Falla f en cada Poste de tiempo i como se muestra en la ec.1

For each Control Variable $C^i_{Failure}$ a restriction is imposed that represents the maximum value that said variable can take for each Failure Step f in each Time-Band i as shown in ec.1

$$C^i_{Failure} \leq C^i_D \cdot Depth^i_f \qquad \text{ec.1.}$$

Dónde:

$C^i_{Failure}$: Potencia de Falla despachada.

C^i_D : Potencia demandada.

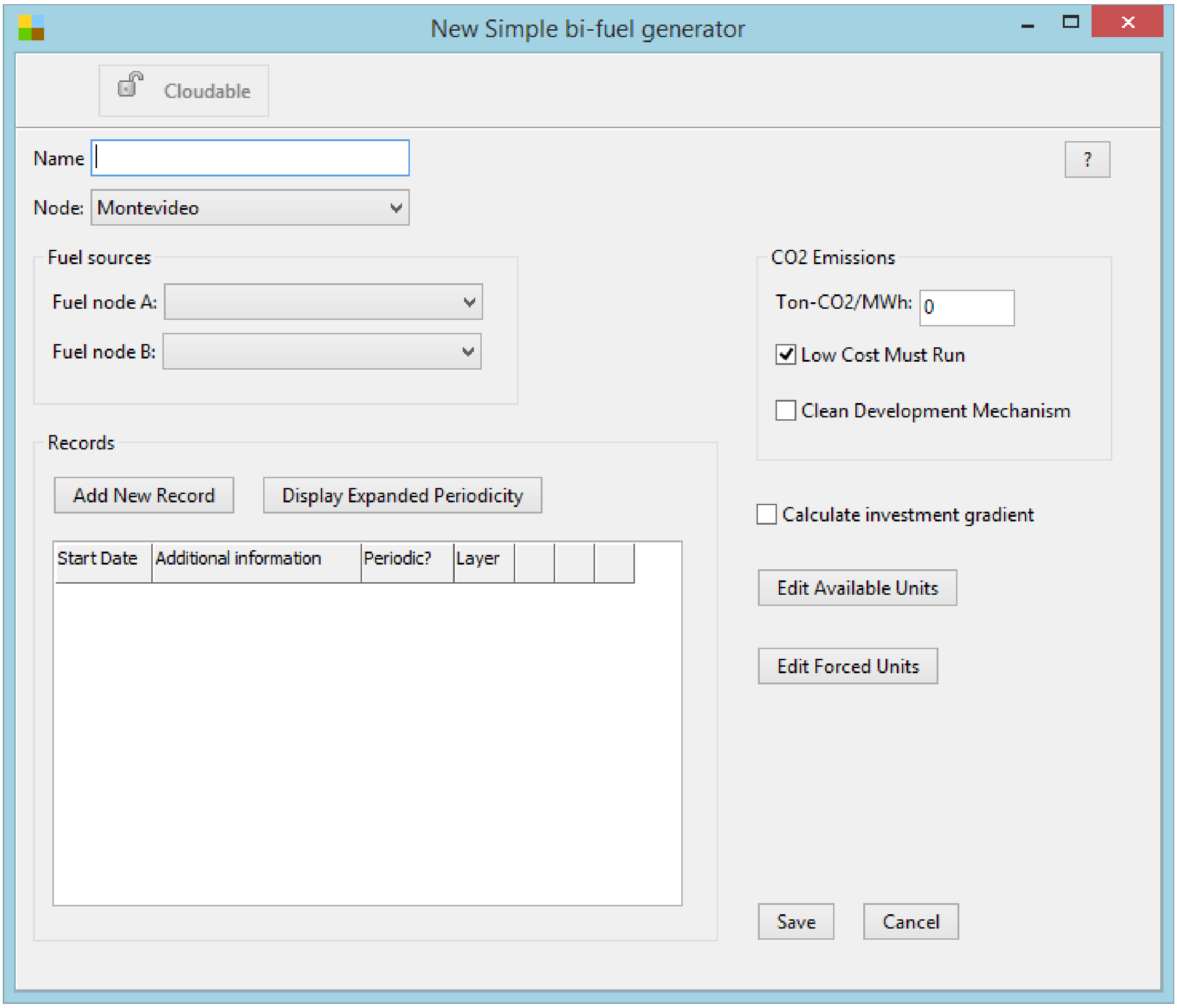
$Depth^i_f$: Profundidad del Escalón de Falla f .

13.6. Simple Bi-fuel Generator.

The Simple Bi-fuel Generator is an Actor belonging to the Fuel Network. The Actor represents a simple thermal generator that connects to two Fuel Nodes (can operate with fuels A and B) and delivers certain electrical power to the system.

13.6.a) Operation description.

The registration form of the Simple Bi-fuel Generator is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

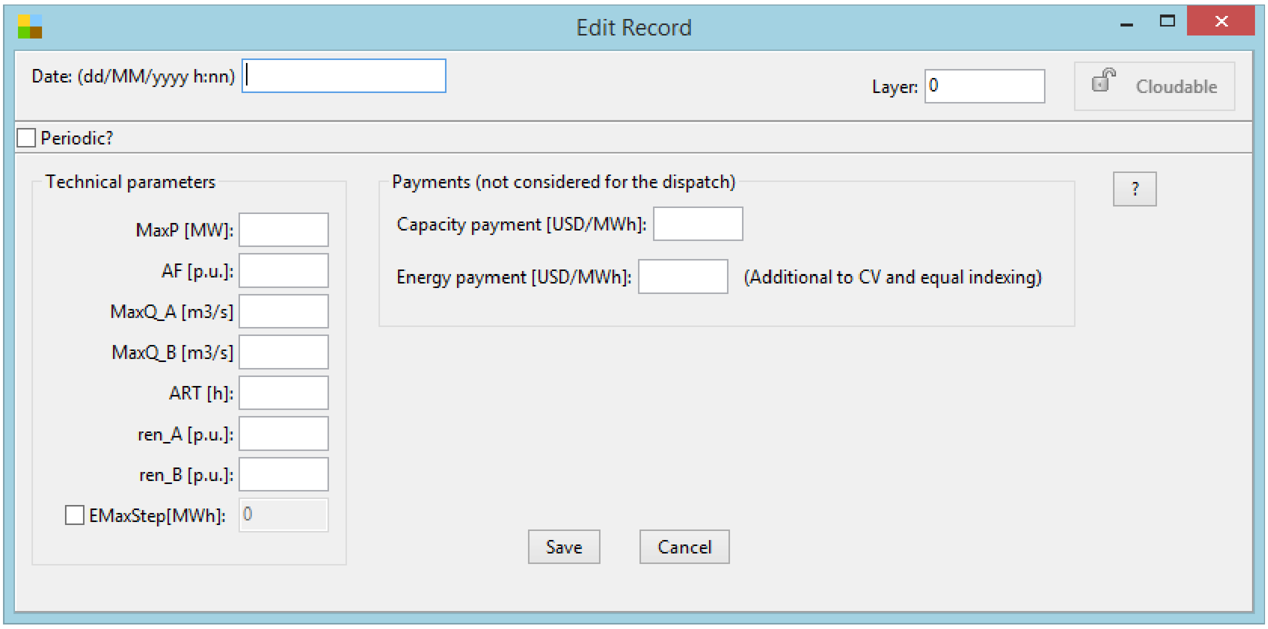
13.6.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network and the Fuel nodes A and B, of the Fuel Network with which you want to associate the Actor.

13.6.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- MaxP: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- AF: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows.
- MaxQ_A: It is the maximum fuel flow A in m3/s that the Actor can extract from the Fuel node to which it is connected.
- MaxQ_B: It is the maximum fuel flow B in m3/s that the Actor can extract from the Fuel node to which it is connected.
- ART: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- ren_A: It is the performance in p.u. of the generator with fuel A.

- ren_B: It is the performance in p.u. of the generator with fuel B.
- EmaxStep: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

13.6.d) Published variables for SimRes.

The Actor allows to publish the following variables per time post:

Name	***Unit***	***Time post***	***SR3***	***Description***
Direct Cost of the Step	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
Power	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
ForcingSCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
CVe	USD/MWh	No	No	Payment for additional energy to the C.V., affected by the price index.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time post.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
NForcedUnits	u	Yes	No	Number of forced units.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
PAverageDispatched	MW	No	Yes	Average power dispatched in the time post.
Q_A y Q_B	m3/s	Yes	Yes	Fuel flow.
alpha	p.u.	Yes	Yes	Percentage of post time that fuel A is used.
EMaxStep	MWh	Yes	No	Maximum energy per time post.

13.6.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds three Control Variables:

- The consumption flows q_{ai} and q_{bi} of fuels A and B in the time post i .
- The precentage of time α of the time post i that the Actor uses fuel A.

The power of the generator in the time post i is shown in ec.1:

$$P_i=(ren_A\,pci_a q_{ai})\alpha_i+(ren_B\,pci_b q_{bi})(1-\alpha_i)$$

ec.1 Bi-fuel Generator Power in the time post i

The variables q_i take values between 0 and Qmax. Pmax is considered to be the same with either of the two fuels A or B.

The parameter pci is the lower calorific value of the fuel supplied and is a parameter of the Fuel Network that supplies fuels A and B.

The variable α_i varies in the interval [0, 1] so at the ends it takes only one fuel per time post i . With any intermediate value, the Actor uses fuel A α_i from time and fuel B $1-\alpha_i$ from time.

For the purpose of being able to represent ec.1 by a linear model, it can be replaced by the equality and inequality restrictions shown in ec.2:

$$P_i=ren_A\,pci_a q_{ai}+ren_B\,pci_b q_{bi}$$
$$q_{ai}\leqslant QMáx_A\alpha_i$$
$$q_{bi}\leqslant QMáx_B(1-\alpha_i)$$

ec.2 Bi-fuel Generator Power in the time post i , linear model.

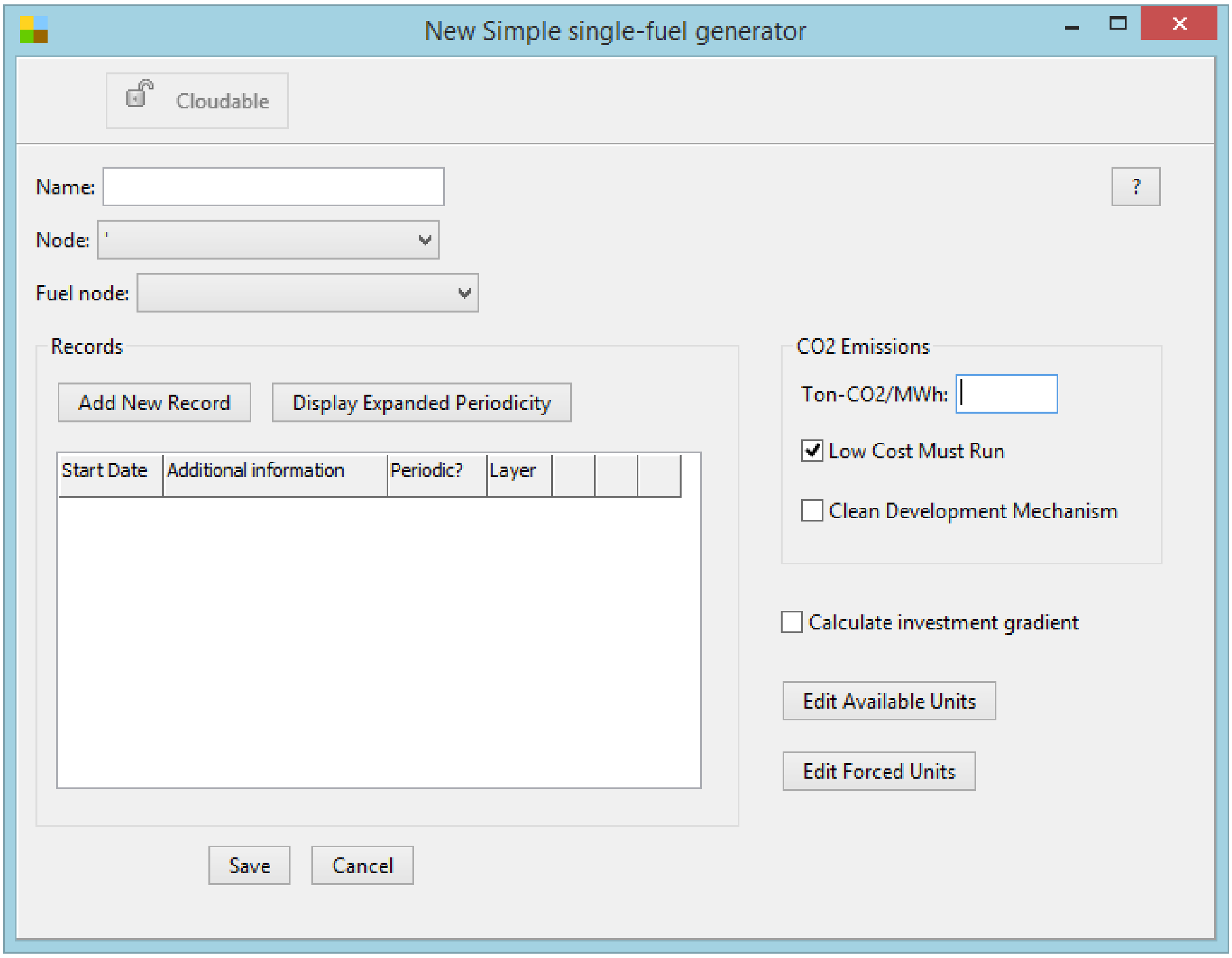
The first row of ec.2 shows the contribution of the Actor to the restriction of the Electric Node to which it is connected. The next two rows are the restrictions that force the generator to use one fuel part of the time and the other fuel the rest of the time, setting the maximum generation for each one.

13.7. Simple Single-fuel Generator.

The Simple Single-fuel Generator is an Actor belonging to the Fuel Network. The Actor represents a simple thermal generator that connects to a Fuel Node and delivers certain electrical power to the system.

13.7.a) Operation description.

The registration form of the Simple Single-fuel Generator is presented below:



The general features of the Actor are described in the document General Characteristics of the Actors.

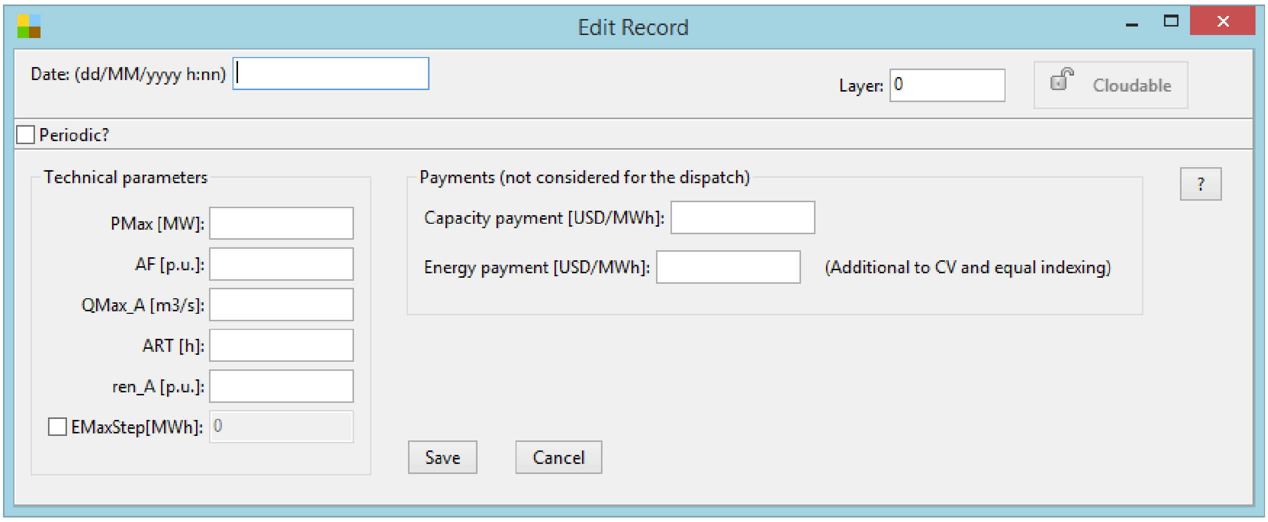
13.7.b) *Static parameters.*

The static parameters are the Name and Node of the Electric Network and the Fuel node of the Fuel Network with which you want to associate the Actor.

13.7.c) *Dynamic parameters.*

The dynamic parameters of the Actor are defined within the Records panel, when adding a new Record. In a new dynamic parameters Record, the effective start date and its periodicity must be defined. Additionally, a list of technical parameters that define the characteristics of the Actor must be specified.

The registration panel of a new Record is shown below:



The technical parameters to specify are:

- Pmax: Maximum power in MW that the Actor can generate and deliver to the Node of the Electric Network.
- FD: It is the generator availability factor in p.u. and determines what percentage of time the Actor is in service and operational outside the scheduled maintenance windows..
- QMax_A: It is the maximum fuel flow A in m3/s that the Actor can extract from the Fuel node to which it is connected.
- TMR: It is the average repair time in hours that the Actor needs to return to service after an event of accidental failure.
- ren_A: It is the performance in p.u. of the generator with fuel A.
- EmaxStep: It is the maximum energy in MWh that the Actor can consume from one Node per time post. If the box is selected, the generator will not be able to consume more energy than the value specified.

13.7.d) Published variables for SimRes.

The Actor allows to publish the following variables per time post:

Name	*Unit*	*Time post*	*SR3*	*Description*
Direct Cost of the Step	USD	No	Yes	Sum of the direct costs incurred in each time post.
Income ByAvailability	USD	No	No	Payments received for availability.
Income ByEnergy	USD	No	No	Payments received for dispatched energy.
Power	MW	Yes	Yes	Power injected into the Node.
Rotating Reserve	MW	No	No	Rotating Reserve.
cv_Spot	USD/MWh	No	No	Spot Variable Cost.
Lambda_P	USD/MWh	No	No	Lagrange multiplier of the box constraint.
Participation SCS	USD	No	No	Participation in the System Reliability Service.
ForcingSCS	USD	No	No	Forcing in the System Reliability Service.
E*cmg	USD	No	Yes	Energy valued at Marginal Generation Cost (If the investment gradient is selected).
InvGrad	-	No	Yes	Investment Gradient.
Cost	USD	Yes	Yes	Total cost associated with payments for energy and availability, variable fuel and non-fuel costs.
NUnitsDispatched	u	Yes	Yes	Number of dispatched units.
CV	USD/MWh	No	No	Incremental variable cost above the technical minimum (affected by the price index) plus the non-combustible variable cost.
CVe	USD/MWh	No	No	Payment for additional energy to the C.V., affected by the price index.
MaxNUnitsDispatchedInTheStep	u	No	Yes	Maximum number of units dispatched in the time post.
NAvailableUnits	u	No	Yes	Number of available units in the time post.
NForcedUnits	u	Yes	No	Number of forced units.
PMaxAvailable	MW	Yes	Yes	Maximun available power.
PAverageDispatched	MW	No	Yes	Average power dispatched in the time post.
Q_A	m3/s	Yes	Yes	Fuel flow.
EMaxStep	MWh	Yes	No	Maximum energy per time post.

13.7.e) State variables, Control and Restrictions.

The Actor does not add State Variables to the system.

The Actor adds one Control Variables:

- The consumption flow q_{ai} of fuel A in the time post i .

The power of the generator in the time post i is shown in ec.1:

$$P_i = ren_A pci_a q_{ai}$$

ec.1 Single-fuel Generator Power in the time post i

The variables q_i take values between 0 and Qmax.

The parameter pci is the lower calorific value of the fuel supplied and is a parameter of the Fuel Network that supplies fuel A.

For the purpose of being able to represent ec.1 by a linear model, it can be replaced by the equality and inequality restrictions shown in ec.2:

$$\begin{gathered} P_i = ren_A pci_a q_{ai} \\ q_{ai} \leqslant QMáx_A \end{gathered}$$

ec.2 Single-fuel Generator Power in the time post i , linear model.

The first row of ec.2 shows the contribution of the Actor to the restriction of the Electric Node to which it is connected, and the next row is the restriction that limits the fuel flow that the generator can consume.