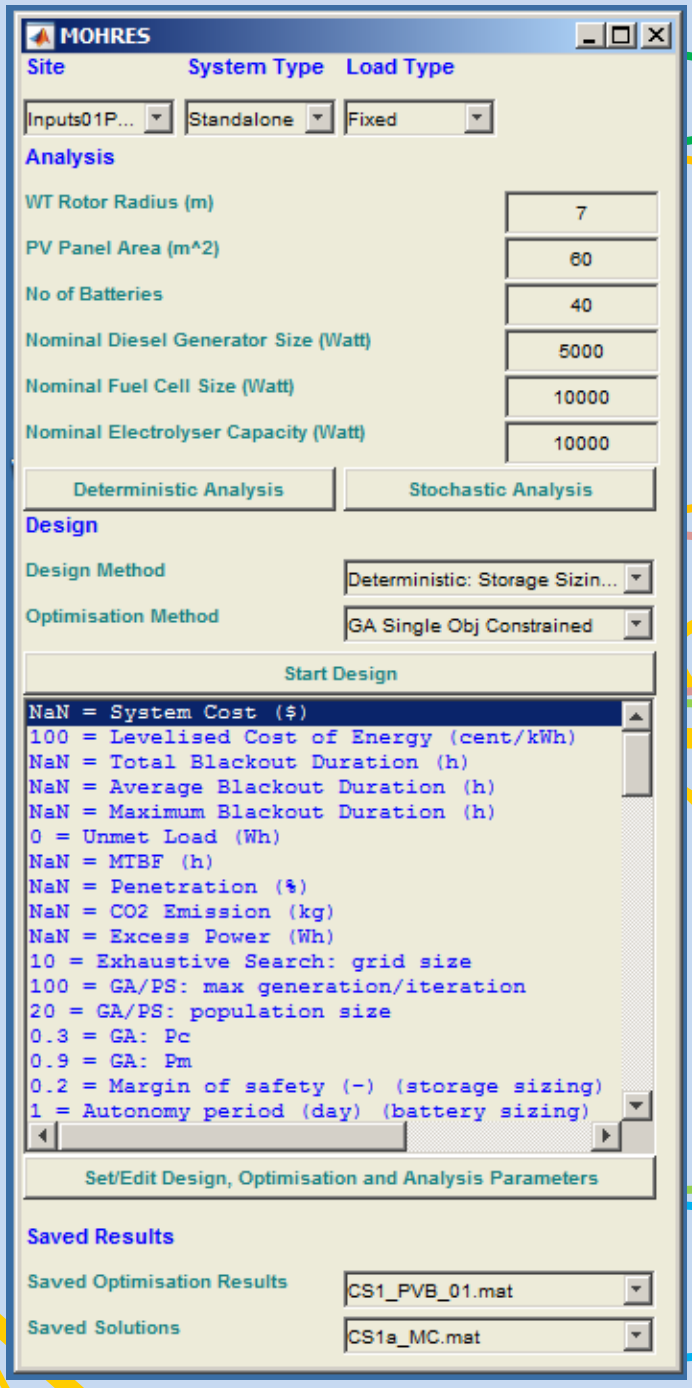
1 MOHRES Main User Interface



Site Data & System Type

- Demand load and renewable resources data
- System type
- Demand load type

Analysis

- System Size
- Analysis Type

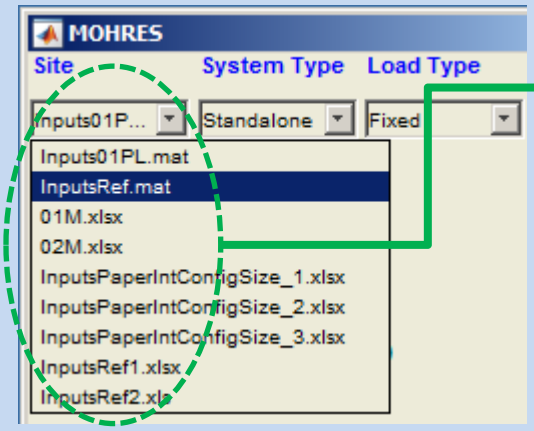
Design

- Design Method
- Optimisation Method

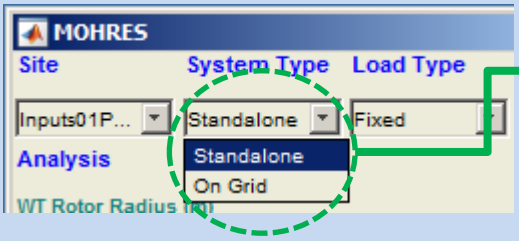
Power & Cost Models, Design & Optimisation Parameters

Load Saved Results

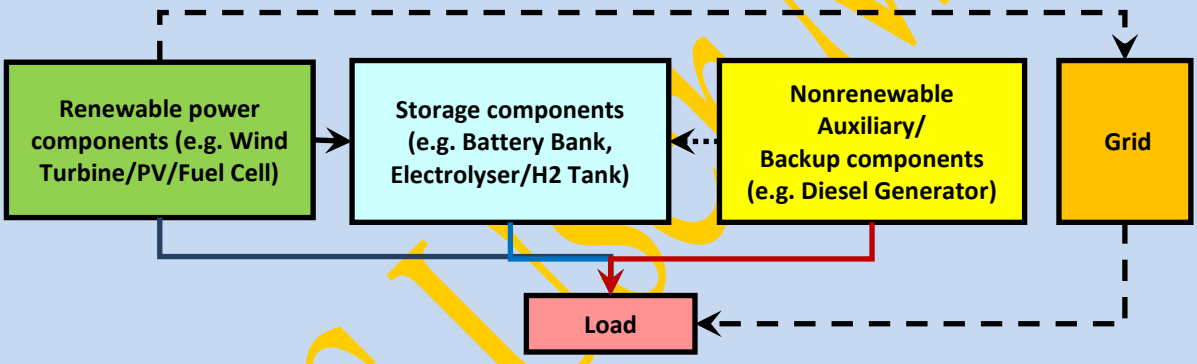
2 Site Data & System Type

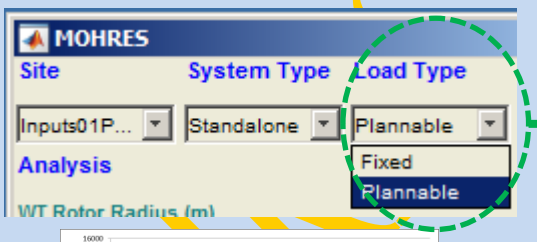


- Select the file including the demand load data and renewable resources at the site location
- Formats: .mat, .xls, .xlsx

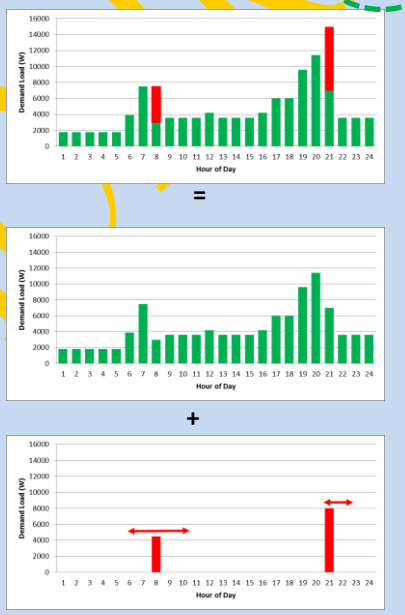


Select the type of the HRES
- Standalone
- On-grid (grid connected)



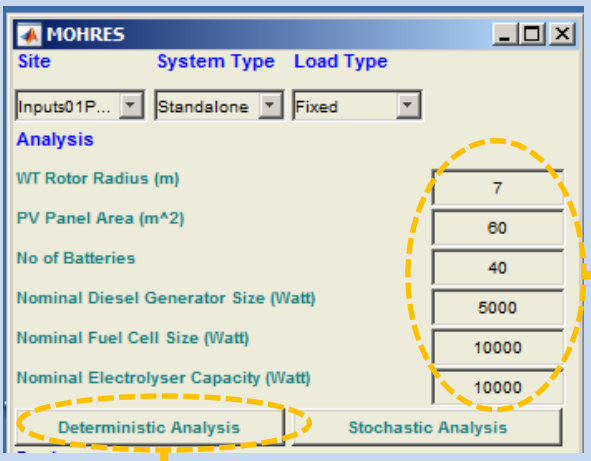


Select the type of demand load
- Fixed: The daily demand load profile is fixed (can change from one day to another but is fixed for each day).
- Plannable: In cases such as industrial loads that the demand load can be divided into fixed and flexible parts (which can be shifted within a specific time window). In such cases MOHRES finds the best load profile.



3 Analysis of a HRES

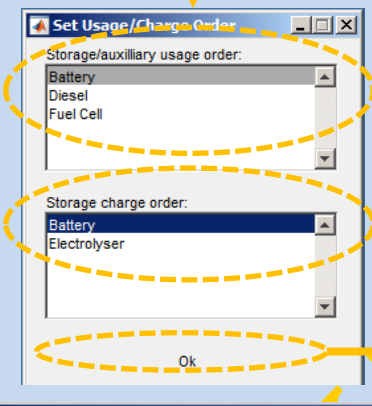
3.1 Deterministic Analysis



- Enter the size of components in the system *(Zero for those components which are not included in the HRES configuration)*

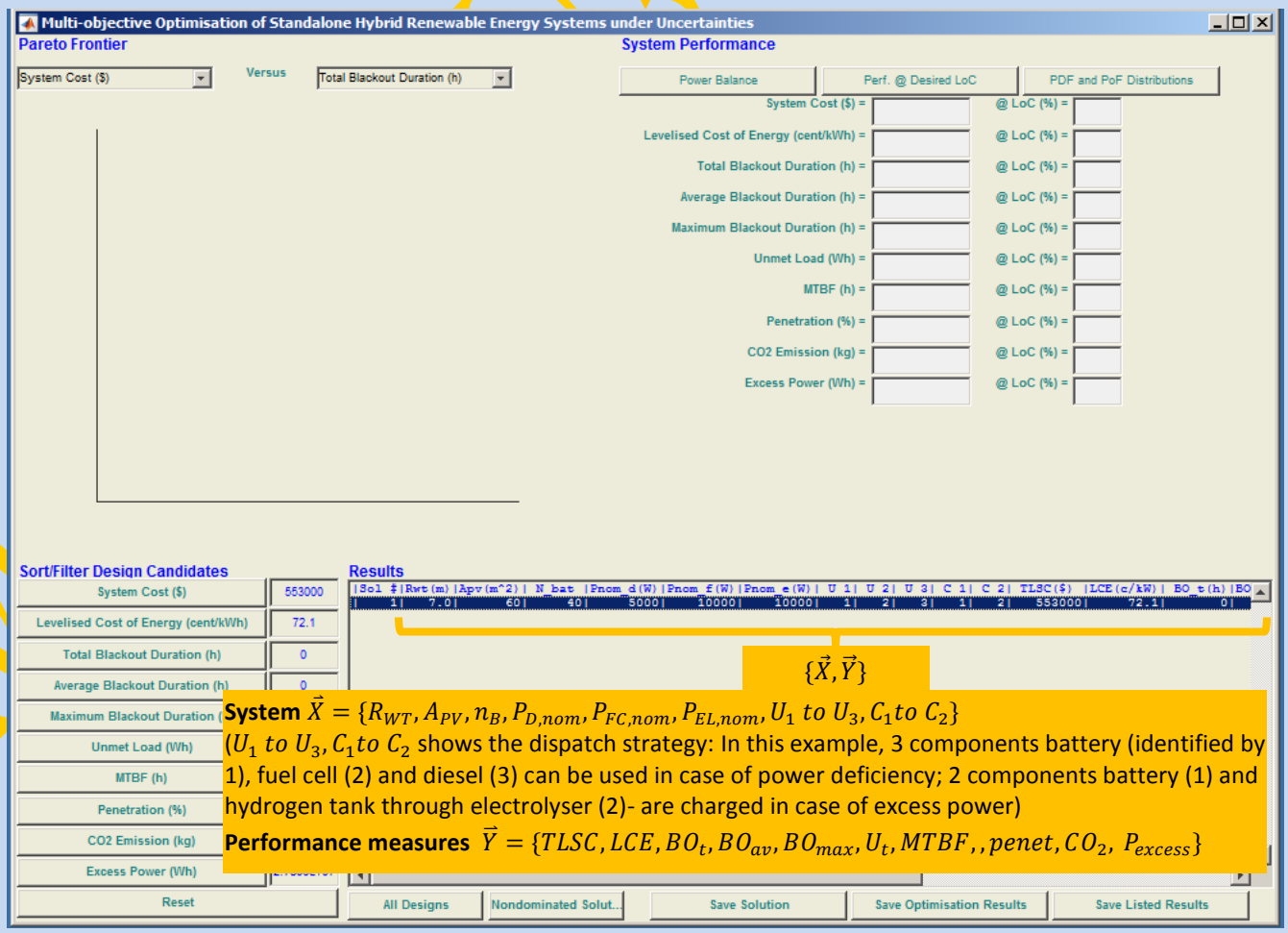
- If required, edit Power & Cost Model parameters

Set/Edit Design, Optimisation and Analysis Parameters



- Set Dispatch Strategy: In configurations with more than one storage/auxiliary/backup component, different dispatch strategies are possible. Define dispatch strategy by setting
  - Usage order
  - Charging order

(Clicking on a component sends it on top of the list)

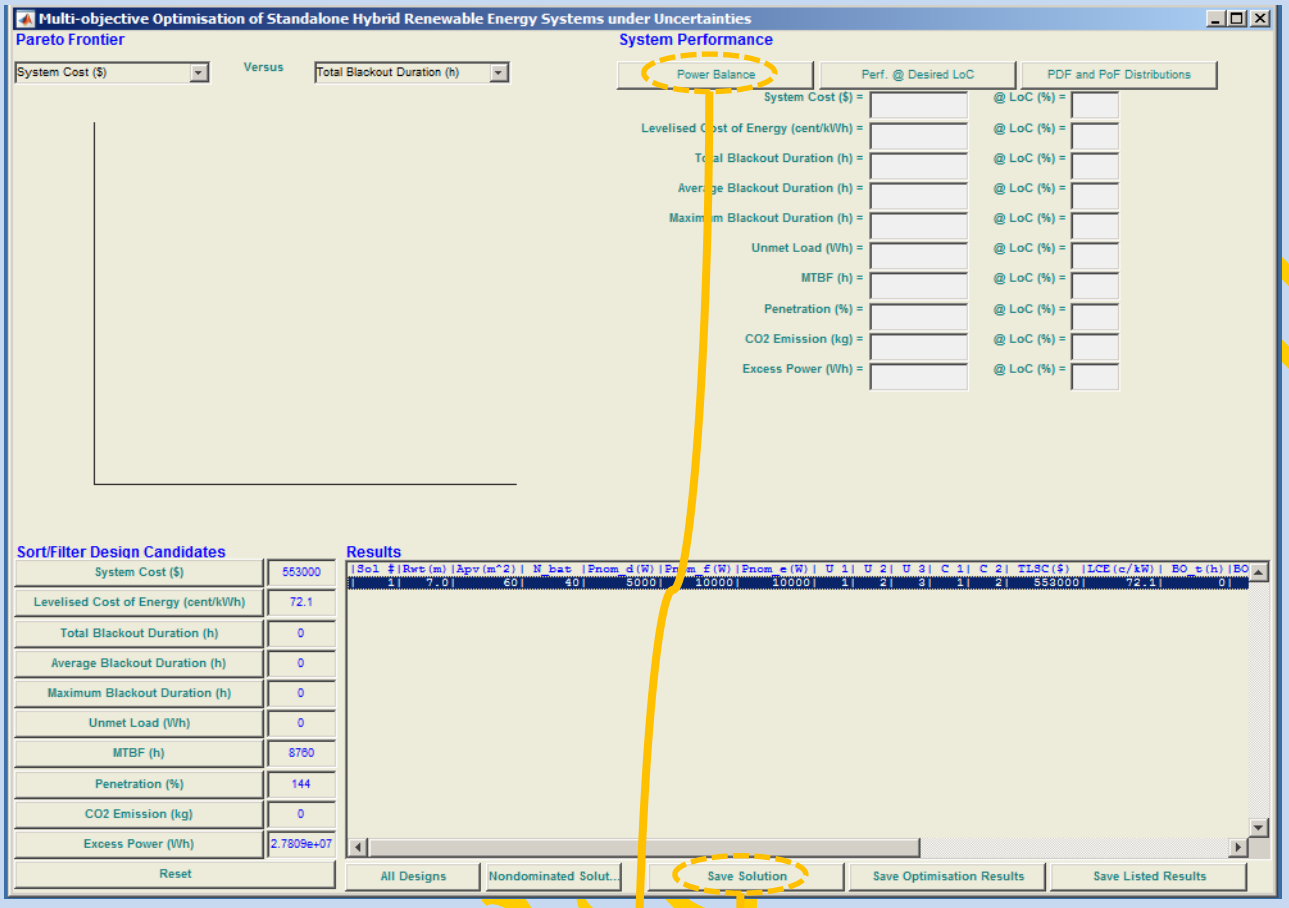


$\{\vec{X}, \vec{Y}\}$

System $\vec{X} = \{R_{WT}, A_{PV}, n_B, P_{D,nom}, P_{FC,nom}, P_{EL,nom}, U_1 \text{ to } U_3, C_1 \text{ to } C_2\}$

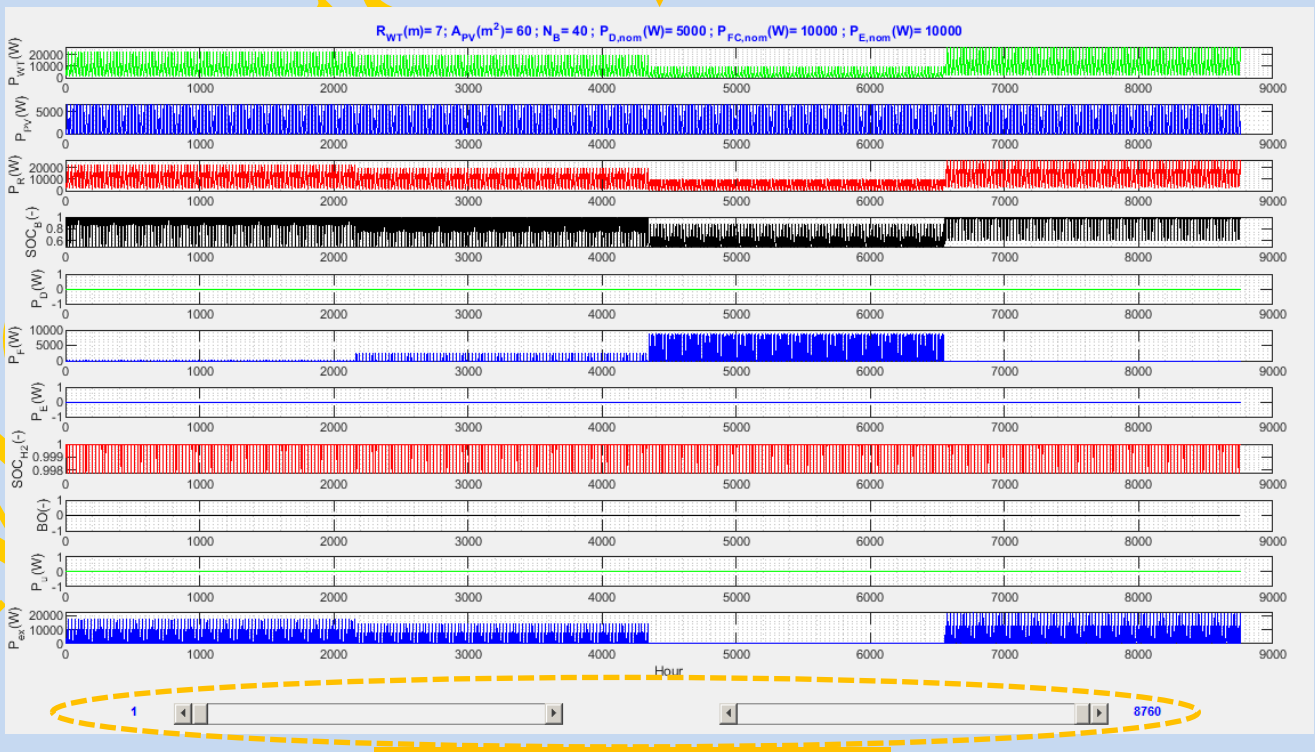
(U_1 *to* U_3, C_1 *to* C_2 shows the dispatch strategy: In this example, 3 components battery (identified by 1), fuel cell (2) and diesel (3) can be used in case of power deficiency; 2 components battery (1) and hydrogen tank through electrolyser (2)- are charged in case of excess power)

Performance measures $\vec{Y} = \{TLSC, LCE, BO_t, BO_{av}, BO_{max}, U_t, MTBF, , penet, CO_2, P_{excess}\}$



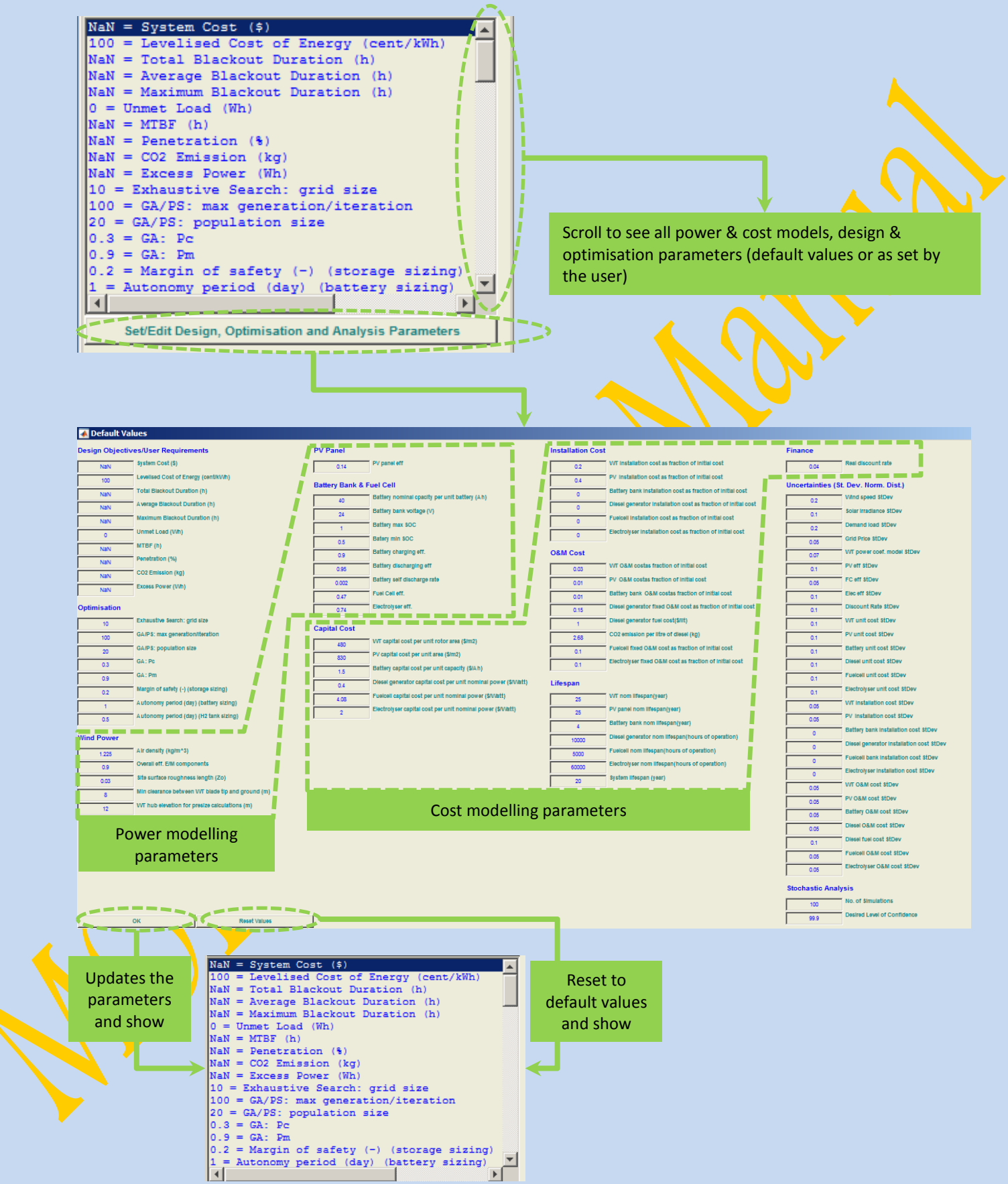
Save solution

Power Balance

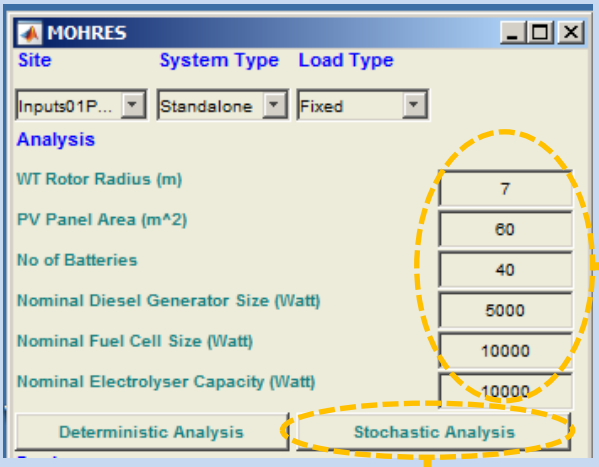


Change the observation window

3.2 Deterministic Analysis-Set/Edit Power & Cost Model parameters



3.3 Nondeterministic (Stochastic) Analysis



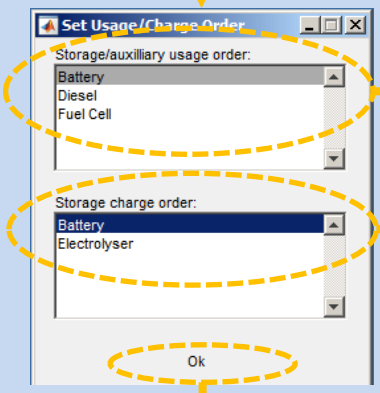
- Enter the size of components in the system

(Zero for those components which are not included in the HRES configuration)

If required, edit /set

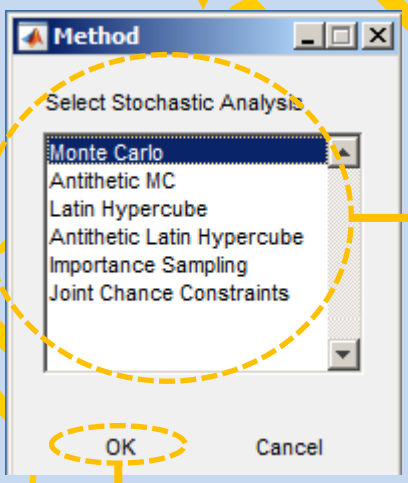
- power & cost model parameters
- uncertainties (pdf for uncertain parameters)
- stochastic simulation parameters
- level of confidence (LoC) at which the performance is calculated (LoC_d)

Set/Edit Design, Optimisation and Analysis Parameters

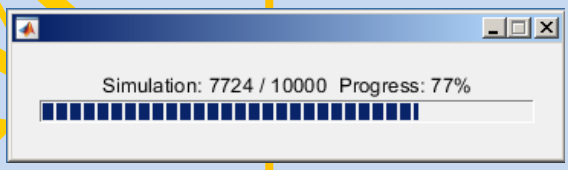


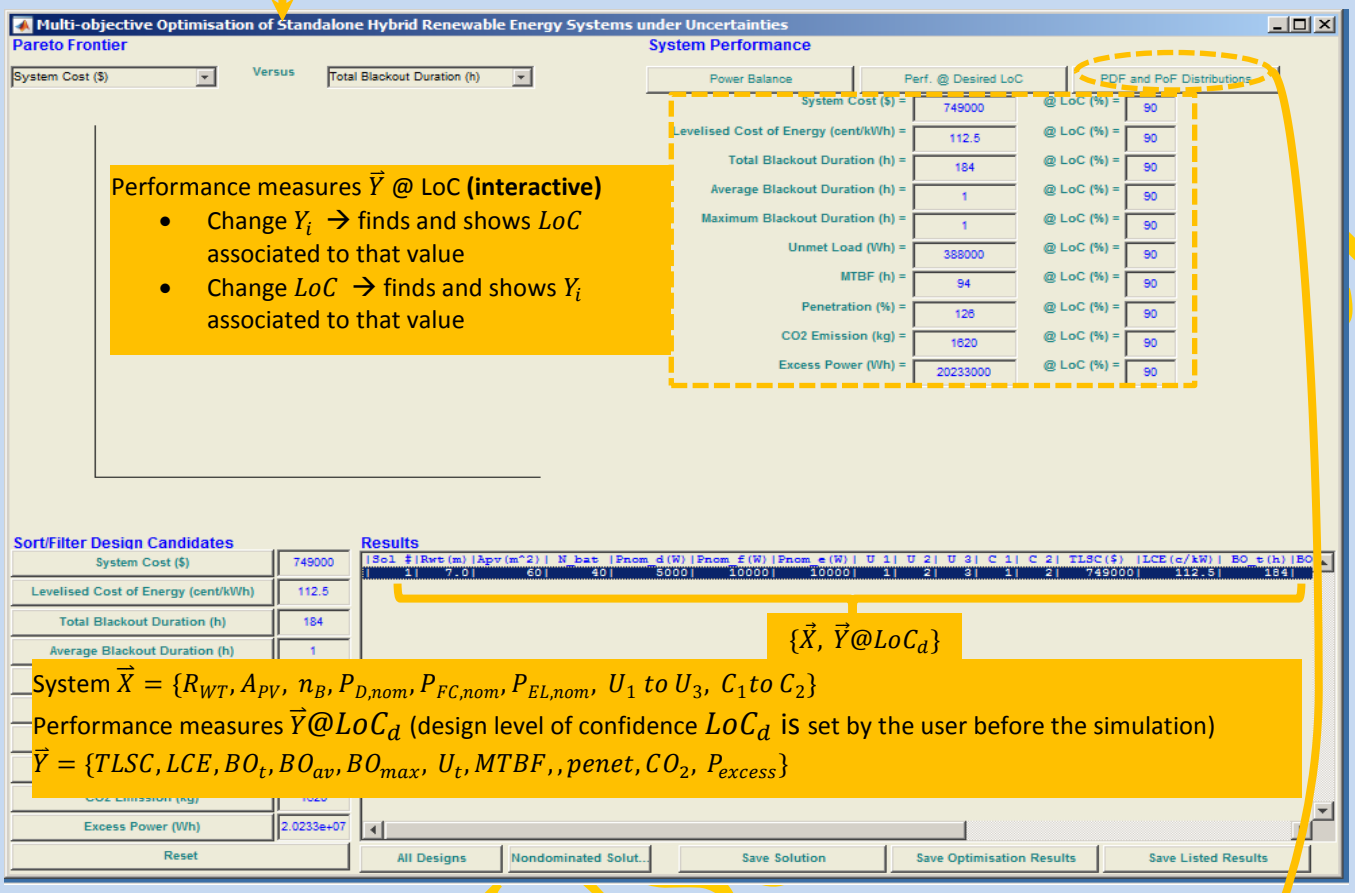
- Set Dispatch Strategy: In configurations with more than one storage/auxiliary/backup component, different dispatch strategies are possible. Define dispatch strategy by setting
  - Usage order
  - Charging order

(Clicking on a component sends it on top of the list)



- Select the stochastic method





Performance measures $\vec{Y}$ @ LoC **(interactive)**

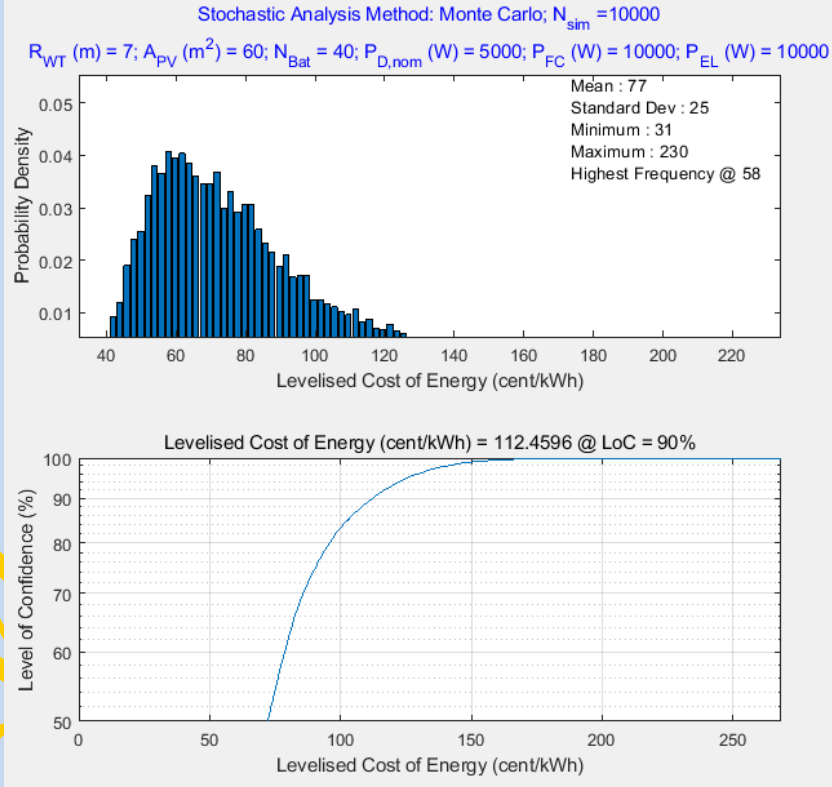
- Change Y_i → finds and shows LoC associated to that value
- Change LoC → finds and shows Y_i associated to that value

$\{\vec{X}, \vec{Y}@LoC_d\}$

System $\vec{X} = \{R_{WT}, A_{PV}, n_B, P_{D,nom}, P_{FC,nom}, P_{EL,nom}, U_1 \text{ to } U_3, C_1 \text{ to } C_2\}$

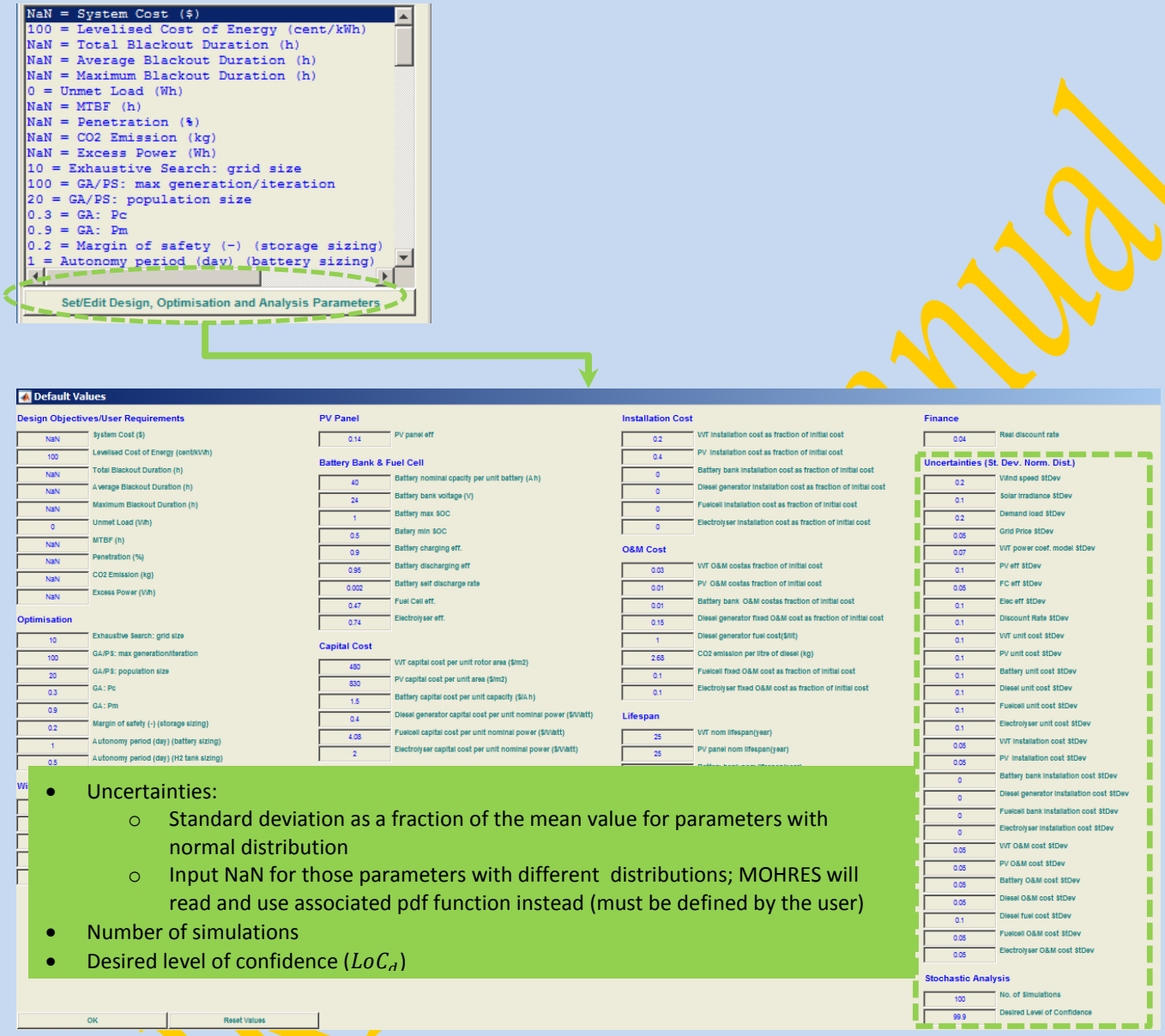
Performance measures $\vec{Y}@LoC_d$ (design level of confidence LoC_d is set by the user before the simulation)

$\vec{Y} = \{TLSC, LCE, BO_t, BO_{av}, BO_{max}, U_t, MTBF, , penet, CO_2, P_{excess}\}$



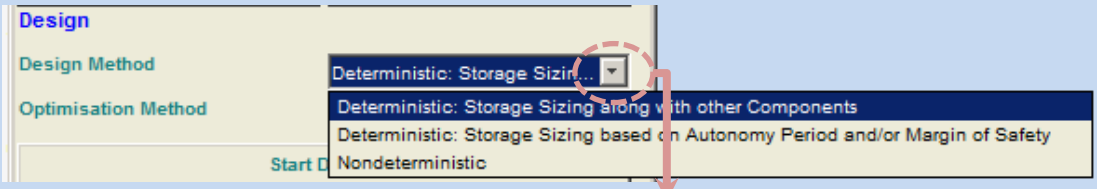
Probability density function (PDF) and level of confidence (LoC) for all performance measure (only LCE is shown here)

3.4 Nondeterministic Analysis-Set/Edit uncertainties and stochastic simulation parameters



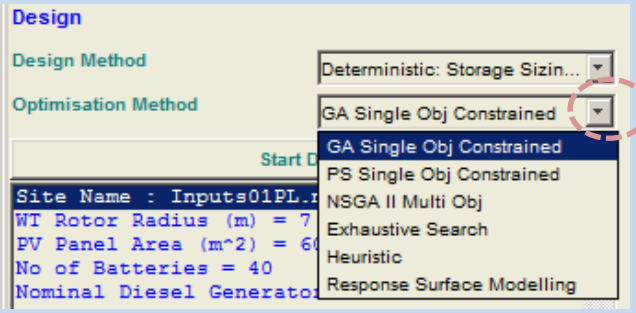
- Uncertainties:
  - Standard deviation as a fraction of the mean value for parameters with normal distribution
  - Input NaN for those parameters with different distributions; MOHRES will read and use associated pdf function instead (must be defined by the user)
- Number of simulations
- Desired level of confidence (LoC_d)

4 Design



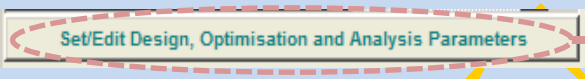
Select Design Method

- Deterministic (based on deterministic system analysis)
  - Storage sizing along with the rest of components
  - Storage sizing based on worst case scenarios (using autonomy period and margin of safety)
- Nondeterministic-runs a stochastic analysis for each design candidate evaluation (runs storage sizing along with the rest of components)



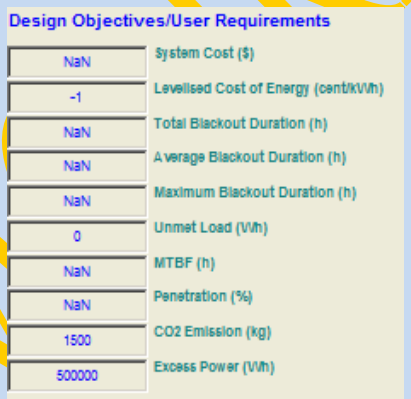
Select Optimisation Method:

- Single objective
  - Genetic Algorithm
  - Particle Swarm
  - Heuristic
  - Response Surface Modelling (best option for nondeterministic design)
  - Exhaustive Search
- Multiobjective
  - NSGA II
  - Response Surface Modelling
  - Exhaustive Search

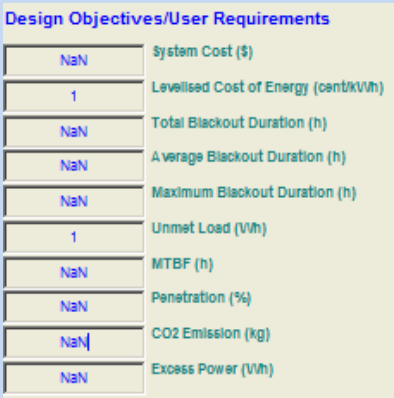


Set objective and constraints (according the following rules):

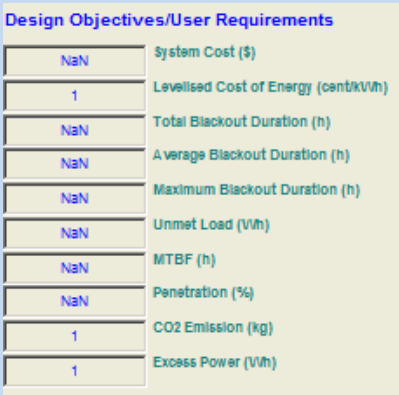
- For single objective optimisation
  - Put an arbitrary negative value for the performance measure which is the optimisation objective
  - Put the constraint value for those performance measures which are constrained
  - Put NaN for those performance measures which are neither objective nor constraint
- For multiobjective optimisation
  - Put an arbitrary positive value for the performance measures which are the optimisation objectives
  - Put NaN for the rest of performance measures
- Examples:



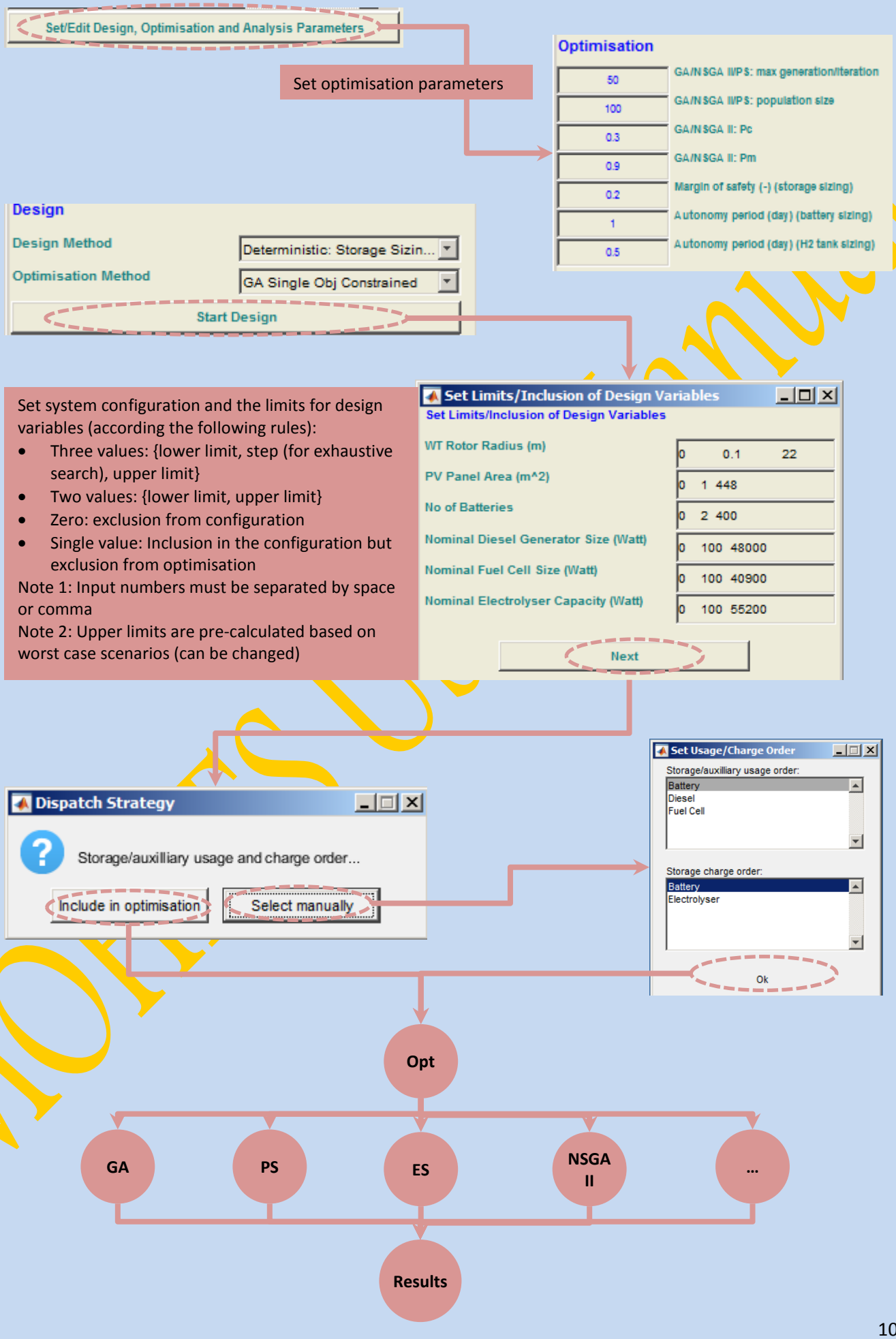
$$min\{LCE\}$$
$$s.t.$$
$$U_t \leq 0$$
$$CO_2 \leq 1500\ kg/year$$
$$P_{excess} \geq 500{,}000\ Wh/year$$

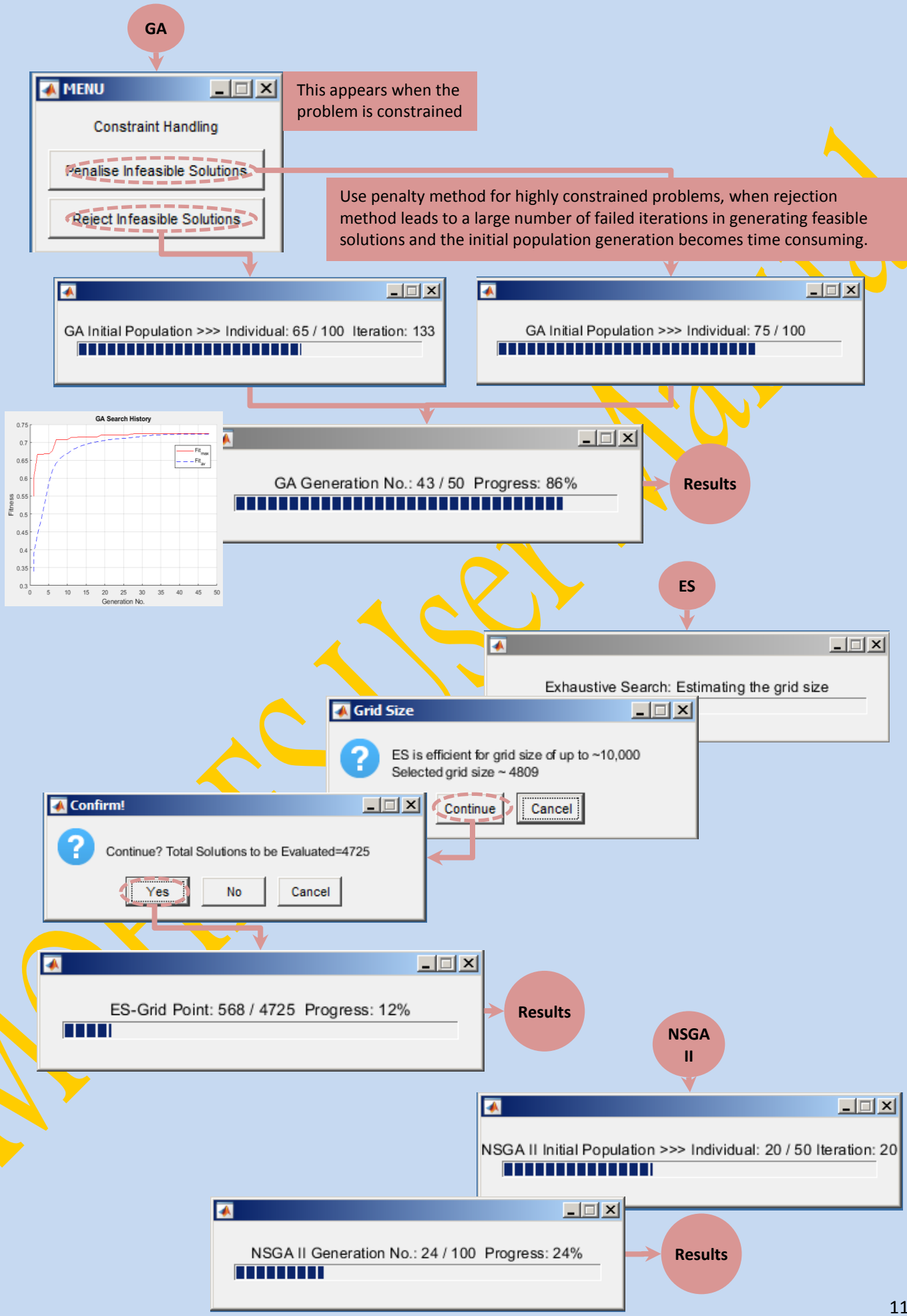


$$min\{LCE\ \&\ U_t\}$$



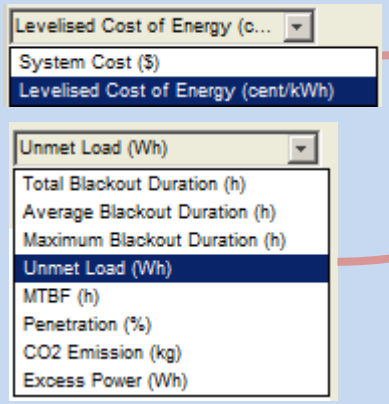
$$min\{LCE\ \&\ CO_2\}\ \&\ max\{P_{excess}\}$$


Set/Edit Design, Optimisation and Analysis Parameters
Set optimisation parameters
Optimisation
50
GA/NSGA II/PS: max generation/iteration
100
GA/NSGA II/PS: population size
0.3
GA/NSGA II: Pc
0.9
GA/NSGA II: Pm
0.2
Margin of safety (-) (storage sizing)
1
Autonomy period (day) (battery sizing)
0.5
Autonomy period (day) (H2 tank sizing)
Design
Design Method
Deterministic: Storage Sizin...
Optimisation Method
GA Single Obj Constrained
Start Design
Set system configuration and the limits for design variables (according the following rules):
• Three values: {lower limit, step (for exhaustive search), upper limit}
• Two values: {lower limit, upper limit}
• Zero: exclusion from configuration
• Single value: Inclusion in the configuration but exclusion from optimisation
Note 1: Input numbers must be separated by space or comma
Note 2: Upper limits are pre-calculated based on worst case scenarios (can be changed)
Set Limits/Inclusion of Design Variables
Set Limits/Inclusion of Design Variables
WT Rotor Radius (m)
0 0.1 22
PV Panel Area (m^2)
0 1 448
No of Batteries
0 2 400
Nominal Diesel Generator Size (Watt)
0 100 48000
Nominal Fuel Cell Size (Watt)
0 100 40900
Nominal Electrolyser Capacity (Watt)
0 100 55200
Next
Dispatch Strategy
Storage/auxilliary usage and charge order...
Include in optimisation
Select manually
Set Usage/Charge Order
Storage/auxilliary usage order:
Battery
Diesel
Fuel Cell
Storage charge order:
Battery
Electrolyser
Ok
Opt
GA
PS
ES
NSGA II
...
Results

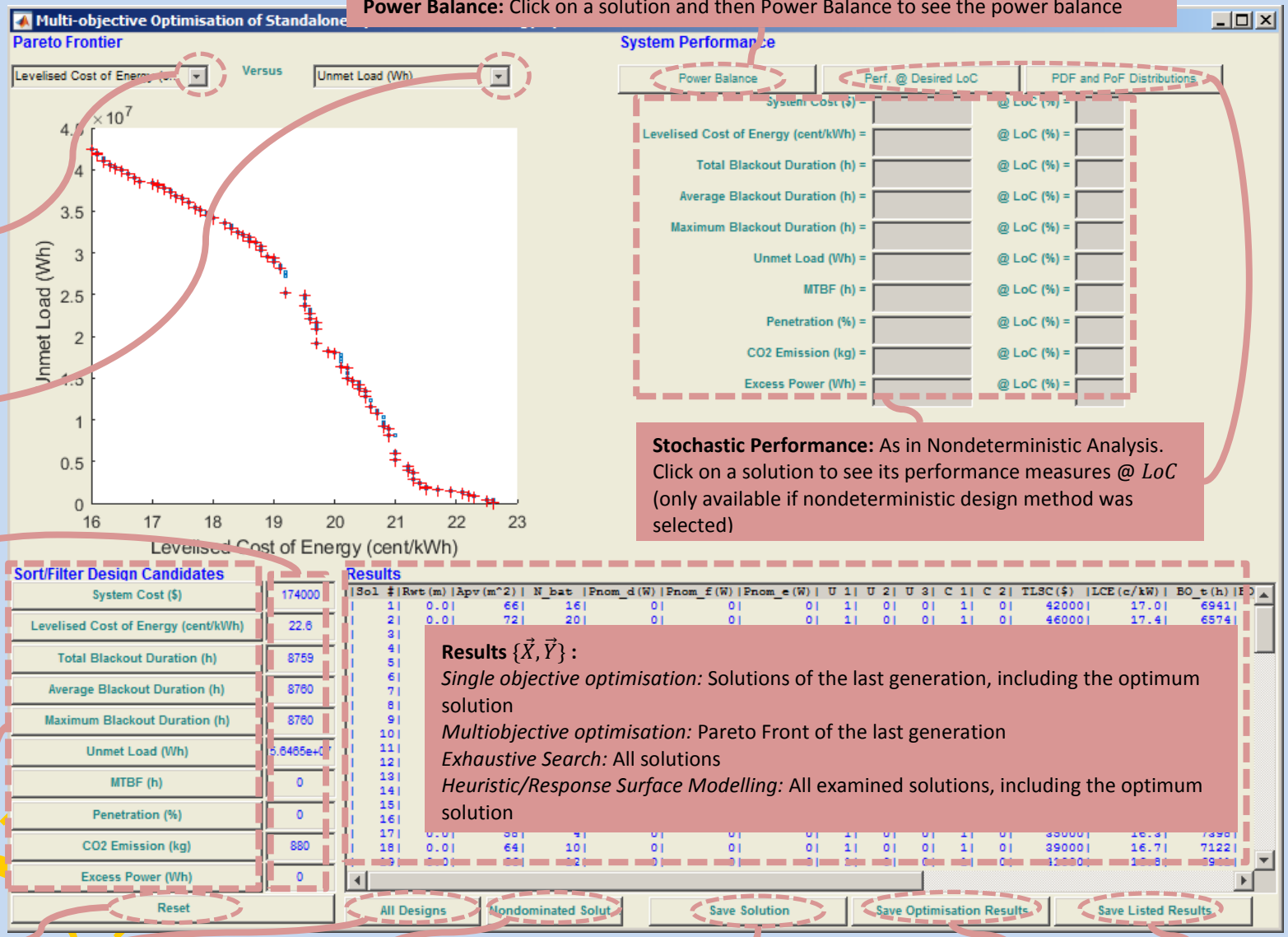

GA
MENU
Constraint Handling
Penalise Infeasible Solutions
Reject Infeasible Solutions
This appears when the problem is constrained
Use penalty method for highly constrained problems, when rejection method leads to a large number of failed iterations in generating feasible solutions and the initial population generation becomes time consuming.
GA Initial Population >>> Individual: 65 / 100 Iteration: 133
GA Initial Population >>> Individual: 75 / 100
GA Search History
Fitness
Generation No.
GA Generation No.: 43 / 50 Progress: 86%
Results
ES
Exhaustive Search: Estimating the grid size
Grid Size
ES is efficient for grid size of up to ~10,000
Selected grid size ~ 4809
Continue
Cancel
Confirm!
Continue? Total Solutions to be Evaluated=4725
Yes
No
Cancel
ES-Grid Point: 568 / 4725 Progress: 12%
Results
NSGA II
NSGA II Initial Population >>> Individual: 20 / 50 Iteration: 20
NSGA II Generation No.: 24 / 100 Progress: 24%
Results

Results

Pareto Front: Solutions marked by red +



Power Balance: Click on a solution and then Power Balance to see the power balance



Stochastic Performance: As in Nondeterministic Analysis. Click on a solution to see its performance measures @ LoC (only available if nondeterministic design method was selected)

Filtering: Enter a value for a performance measure to filter out those solutions not satisfying that constraint

Sorting: Click on a button to sort solutions based on that performance measure

Reset: Reset back to all unfiltered and unsorted solutions

Results $\{\vec{X}, \vec{Y}\}$ **:**
Single objective optimisation: Solutions of the last generation, including the optimum solution
Multiobjective optimisation: Pareto Front of the last generation
Exhaustive Search: All solutions
Heuristic/Response Surface Modelling: All examined solutions, including the optimum solution

Shows all solutions

Nondominated Solutions: Filters and shows nondominated solutions

Save Solutions: Click on a solution and then Save Solution

Save: Saves all solutions

Save: Saves only listed solutions

5 Excel Data File for Site Data

demand_m | demand_o | vref | ir | gridprice | others

Site data excel file includes 6 tabs:

- ***demand_m***: averaged daily demand load associate to machinery for load planning (if chosen by the user). Cells must be zero if there is no machinery (plannable) load
- ***demand_o***: contains the rest of the demand load.
- ***vref***: averaged wind speed at a reference elevation (zref)
- ***ir***: averaged solar irradiance
- ***gridprice***: cost of buying electricity from grid for different hours of a day
- ***others***

Format for 'demand_m', 'demand_o', 'vref', 'ir' and 'gridprice':

- 12 typical days, each representing one month.
- Other acceptable formats:
  - 52: each for one week
  - 365: each for one day

24 'hourly' averaged values ($\Delta t = 1\ hr$)
Other formats: any other value for Δt is acceptable
(Δt must be given in tab 'others')

	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	10	10	10	20	20	20	10	10	10	10	10	10
8	40	40	40	130	130	130	80	80	80	30	30	30
9	220	220	220	330	330	330	150	150	150	190	190	190
10	430	430	430	530	530	530	370	370	370	390	390	390
11	610	610	610	690	690	690	500	500	500	560	560	560
12	750	750	750	810	810	810	570	570	570	690	690	690
13	810	810	810	870	870	870	600	600	600	750	750	750
14	810	810	810	850	850	850	590	590	590	750	750	750
15	730	730	730	770	770	770	550	550	550	680	680	680
16	590	590	590	620	620	620	450	450	450	540	540	540
17	410	410	410	450	450	450	330	330	330	370	370	370
18	200	200	200	270	270	270	190	190	190	170	170	170
19	40	40	40	110	110	110	70	70	70	20	20	20
20	10	10	10	10	10	10	10	10	10	10	10	10
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

demand_m | demand_o | vref | ir | gridprice | others

	1	2	3	4	5	6
1	0.2	0.1	0.2	0.05	3	1
2						

demand_m | demand_o | vref | ir | gridprice | others

Tab 'others' include

- zref (elevation at which 'vref' is given
- Δt

Tab 'others' include

- standard deviations for the demand load (demand_o part), wind speed, solar irradiance and grid price
- standard deviations can be overwritten in

Set/Edit Design, Optimisation and Analysis Parameters

Uncertainties (St. Dev. Norm. Dist.)

0.2	Wind speed StDev
0.1	Solar irradiance StDev
0.2	Demand load StDev
0.05	Grid Price StDev