

Case Study 2- Design of a Standalone HRES based on End-User Requirements

The end-user looks for the cheapest system possible. They can tolerate the **power cuts of up to three hours** as long as the **average time between two consecutive power cuts is more than two days**.

Background Theory:

- Integrated Configuration-Size Optimisation
- Implementation of User Requirements using BO distribution and MTBF
- Deterministic Design
- Dispatch Strategy as Design Variable
- Single Objective Optimisation
- Genetic Algorithm

The screenshot displays the MOHRES software interface with several key windows and parameters highlighted:

- MOHRES Main Window:**
 - Site: InputsSa...
 - System Type: Standalone
 - Load Type: Fixed
- Design Objectives/User Requirements:**

-1	System Cost (\$)
NaN	Levelised Cost of Energy (cent/kWh)
NaN	Total Blackout Duration (h)
NaN	Average Blackout Duration (h)
3	Maximum Blackout Duration (h)
NaN	Unmet Load (Vh)
48	MTBF (h)
NaN	Penetration (%)
NaN	CO2 Emission (kg)
NaN	Excess Power (Vh)
- Optimisation Parameters:**

50	GA/NSGA I/PS: max generation/iteration
50	GA/NSGA I/PS: population size
0.3	GA/NSGA II: P _c
0.9	GA/NSGA II: P _m
0.2	Margin of safety (-) (storage sizing)
1	Autonomy period (day) (battery sizing)
0.5	Autonomy period (day) (H2 tank sizing)
- Design Method:** Deterministic: Storage Sizin...
- Optimisation Method:** GA Single Obj Constrained
- 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
- Dispatch Strategy:** Storage/auxiliary usage and charge order...
 - Buttons: Include in optimisation, Select manually

Optimization Constraints:

$$\min\{TLSC\}$$

$$s. t.$$

$$BO_{max} \leq 3 \text{ hr}$$

$$MTBF \geq 48 \text{ hr}$$

GA search parameters:

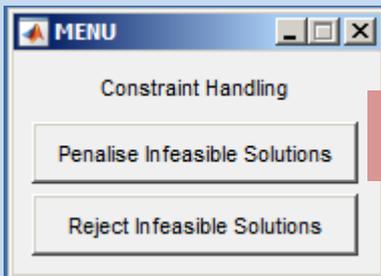
- Deterministic: Storage sizing along with other components
- Genetic Algorithm

Design Variable Limits:

- Lower and upper limits populated automatically
- Upper limits are calculated based on worst case scenarios (editable)
- Steps, also populated automatically, do not apply to genetic algorithm (MOHRES ignores them here)
- All lower limits are set to zero to allow reducing the configuration from a full generic Wind-PV-Battery-Diesel-Fuel cell/Electrolyser to any other potential configuration

Dispatch Strategy:

- Include in optimisation: Add dispatch strategy to the set of design variables



- Reject Infeasible Solutions (this optimisation problem is not too constrained/design space is not too rigid)

Multi-objective Optimisation of Standalone Hybrid Renewable Energy Systems under Uncertainties

Pareto Frontier

System Cost (\$) Versus Total Blackout Duration (h)

System Performance

Power Balance Perf. @ Desired LoC PDF and PoF Distributions

System Cost (\$) = @ LoC (%) =
 Levelised Cost of Energy (cent/kWh) = @ LoC (%) =
 Total Blackout Duration (h) = @ LoC (%) =
 Average Blackout Duration (h) = @ LoC (%) =
 Maximum Blackout Duration (h) = @ LoC (%) =
 Unmet Load (Wh) = @ LoC (%) =
 MTBF (h) = @ LoC (%) =
 Penetration (%) = @ LoC (%) =
 CO2 Emission (kg) = @ LoC (%) =
 Excess Power (Wh) = @ LoC (%) =

Click TLSC (the objective) to sort all solutions based on their TLSC → The top solution (Sol #1) has the lowest TLSC (optimum solution)

The entire population of the last generation of the GA search are shown here; all satisfy the constraints

Sort/Filter Design Candidates

Sol #	Rwt (m)	Apr (m ²)	N bat	Pn	d (W)	Pnom E (W)	Pnom e (W)	U 1	U 2	U 3	C 1	C 2	TLSC (\$)	LCE (c/kWh)	BO t (h)	BO av (h)	BO max (h)	U 1	U 2	U 3	C 1	C 2	TLSC (\$)	LCE (c/kWh)	BO t (h)	BO av (h)	BO max (h)	U 1	U 2	U 3	C 1	C 2	TLSC (\$)	LCE (c/kWh)	BO t (h)	BO av (h)	BO max (h)							
1	0.0	264	212	0	0	0	0	1	0	0	1	0	169000	22.4	184	184	184	184	184	184	184	184	169000	22.4	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184			
2	0.0	266	210	0	0	0	0	1	0	0	1	0	170000	22.5	184	184	184	184	184	184	184	184	170000	22.5	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184

System Cost (\$) 171000

Levelised Cost of Energy (cent/kWh) 22.4

Total Blackout Duration (h) 184

Average Blackout Duration (h) 184

Maximum Blackout Duration (h) 184

Unmet Load (Wh) 0

MTBF (h) 184

Penetration (%) 184

CO2 Emission (kg) 60

Excess Power (Wh) 9.844e+06

Reset All Designs Nondominated Solution Save Solution Save Optimisation Results Save Listed Results

- $\vec{X}_{opt} = \{R_{WT}, A_{PV}, n_B, P_{D,nom}, P_{FC,nom}, P_{EL,nom}, U_1 \text{ to } U_3, C_1 \text{ to } C_2\} = \{0, 264, 212, 0, 0, 0, 1, 0, 0, 1, 0\}$;
- The only storage/auxiliary unit in the system is battery: $U_1 = 1$ (Battery), $U_2 = U_3 = 0$; $C_1 = 1$ (Battery), $C_2 = 0$
- $\vec{Y}_{opt} = \{TLSC, LCE, BO_t, BO_{av}, BO_{max}, U_t, MTBF, penet, CO_2, P_{excess}\} = \{169000, 22.4, 184, 2, 2, 893000, 93, 130, 0, 9915000\}$

