Transición energética en la 4ta revolución industrial
Open Source Tool for Sizing Hybrid Islanded Microgrids in Colombia

Authors: Wilmer Ropero-Castaño, Nicolás Muñoz-Galeano, Eduardo Caicedo-Bravo, Pablo Maya-Duque

Institutions: Universidad de Antioquia
Contents

I. Introduction

II. Theoretical aspects

III. Proposed methodology

IV. Results

V. Conclusions

VI. Questions
I. Introduction

According IPSE (Institute for Planning and Promoting Energy Solutions for Non-Interconneted Zones) in Colombia:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>National territory</td>
<td>53 %</td>
</tr>
<tr>
<td>Users with service</td>
<td>228,295</td>
</tr>
<tr>
<td>Users without service</td>
<td>441,000</td>
</tr>
<tr>
<td>Total capacity</td>
<td>299,394 kW</td>
</tr>
<tr>
<td>Capacity of diesel</td>
<td>89%</td>
</tr>
<tr>
<td>FNCER</td>
<td>11%</td>
</tr>
</tbody>
</table>
II. Theoretical aspects

Architecture considered

- PV array
- Battery Bank
- Charge Controller
- Inverter
- Diesel Generator
- DC BUS
- AC BUS
- Load

optimization technique

Classical
- LP
- MILP

Metaheuristics
- MOGA, MOPSO, ABC, ACO, PSO, GA...

Software
- HOMER
II. Theoretical aspects

\[ P_{pv_t} = N_{pv} \cdot P_{pv_{stc}} \cdot \frac{G(\beta, \alpha)}{G_{stc}} \cdot T \cdot f_{pv} \]

\[ T = \left(1 + \frac{a_p}{100} \cdot (T_{cell_t} - T_{stc})\right) \]

\[ T_{cell_t} = T_{amb} + G(\beta, \alpha)_t \cdot \left(\frac{NOCT - 20}{800}\right) \]

\[ \text{SoC}_t = (1 - \sigma) \cdot \text{SoC}_{t-1} + E_{bat_t^+} \cdot \eta_c - \frac{E_{bat_t^-}}{\eta_{inv}} \]

\[ E_{batn} = N_{bat} \cdot P_{bat_{cell}} \]

\[ N_{bat} = N_{bp} \cdot N_{bs} \]

\[ N_{bs} = \frac{V_{dc_{sist}}}{V_{dc_{bc}}} \]

\[ B_{cycles} = \frac{\sum E_{bat_t^-}}{E_{batn}} \]

\[ \text{SoC}_{\text{max}} = E_{batn} \]

\[ \text{SoC}_{\text{min}} = E_{batn} \cdot (1 - DOD_{\text{max}}) \]

\[ P_{dg} = \eta_{dg} \cdot P_{dg_{rate}} \cdot N_{dg} \]

\[ F_{dg_i} = \sum_{i=1}^{N} a_i + b_i \cdot P_{dg_i} + c_i \cdot P_{dg_i}^2 \]
## II. Theoretical aspects

### Objective function:

$$\sum_{t \in T} \left( cpv \cdot (P_{pv_t} + P_{bat_t}^{pv}) + cdg \cdot (P_{dg_t} + P_{bat_t}^{dg}) + cbat \cdot E_{bat_t}^- + cens \cdot PENS_t \right)$$

### Photovoltaic panel output:

- $P_{pv_t} + P_{bat_t}^{pv} \leq P_{pv_t}^{max}$
- $P_{pv_t} + P_{bat_t}^{pv} \geq P_{pv_t}^{min}$

### Battery bank State Of Charge:

- $SoC_{min} \leq SoC_t \leq SoC_{max}$

### Battery Bank Charge and Discharge constraints:

- $E_{bat_t}^+ = P_{bat_t}^{pv} + P_{bat_t}^{dg} \cdot \eta_{inv}$
- $M_b \cdot B_{ct} \leq E_{bat_t}^+ \leq E_{max} \cdot B_{ct}$
- $M_b \cdot B_{dt} \leq E_{bat_t}^- \leq E_{max} \cdot B_{dt}$

### Diesel generator output:

- $P_{dg_t} + P_{bat_t}^{dg} \leq P_{dg}^{rate} \cdot B_{dg_t}$
- $P_{dg_t} + P_{bat_t}^{dg} \geq P_{dg_t}^{min} \cdot B_{dg_t}$

### Meet the load:

$P_{pv_t} + P_{dg_t} + E_{bat_t}^- + PENS_t = P_{load} \ \forall t \in T$

- $P_{bat_t}^{dg} \leq P_{dg}^{rate} - P_{dg_t}$
- $B_{cycles} \leq cycles_{max}$

### Reliability constraint:

$$\frac{\sum_{t \in T} P_{PENS,t}}{\sum_{t \in T} P_{load,t}} \leq LPSP_{max}$$
III. Proposed methodology

1. Input meteorological data, load profile, reliability constraint and economical data.
2. Input technical parameters and number of PV panels, diesel generator and battery cells.
3. Execute optimization model.
4. Calculate economic indicators.
5. Determine if the solution is optimal.
6. If optimal, accept the solution. Otherwise, repeat steps 2-5.

End.
IV. Results

IV. Results
IV. Results

Optimizer

Optimizer Gurobi

Time Limit: 0.0000
MIP GAP: 0.05000000

Save

[Image of file selection window]
IV. Results
IV. Results
IV. Results
IV. Results

In table it is shown the result to supply the energy demand of the community of “Santa Cruz del Islote” located in Bolivar, Colombia. This community has a high demand of energy at night and has a median of consumption of 24 kWh and a maximum of 47 kWh in October. The solar radiation is over 800 $Wh/m^2$ in March.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of PV cell</td>
<td>Units</td>
<td>80</td>
</tr>
<tr>
<td>Battery Bank</td>
<td>kW</td>
<td>50.4</td>
</tr>
<tr>
<td>Diesel Genset Capacity</td>
<td>kW</td>
<td>50</td>
</tr>
<tr>
<td>Loss of Power Supply Probability</td>
<td>%</td>
<td>6.21</td>
</tr>
</tbody>
</table>
V. Conclusions

- In this paper was developed a open-source tool for sizing islanded MGs which includes solar and diesel generator, and batteries.
- This tool considers a deterministic optimization model.
- The optimization model considers the technical constraint of battery like maximum cycles allowed of charging and discharging.
- The reliability of the system was included as a constraint on the optimization model and the energy no supplied to the load was treated as a variable with a high cost in the objective function.
- It is possible to visualize the results in a friendly dashboard that can help to the users in the decision making by the easy configuration and visualization of results.
VI. Questions