Sizing Photovoltaic-Geothermal Smart Microgrid with Battery Storage Interface

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2. Program Implementation
3. Results
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1. INTRODUCTION

- What is renewable energy?
- Why is renewable energy important?
- Solar Energy and Geothermal Energy
- Microgrids
- The goals
- Greenhouse: solar energy, geothermal energy and biomass
- This project is supported through the program "Parteneriate in domenii prioritare – PN II", by MEN – UEFISCDI, project no. 53/01.07.2014.

2. PROGRAM IMPLEMENTATION

2.1. Interface structure

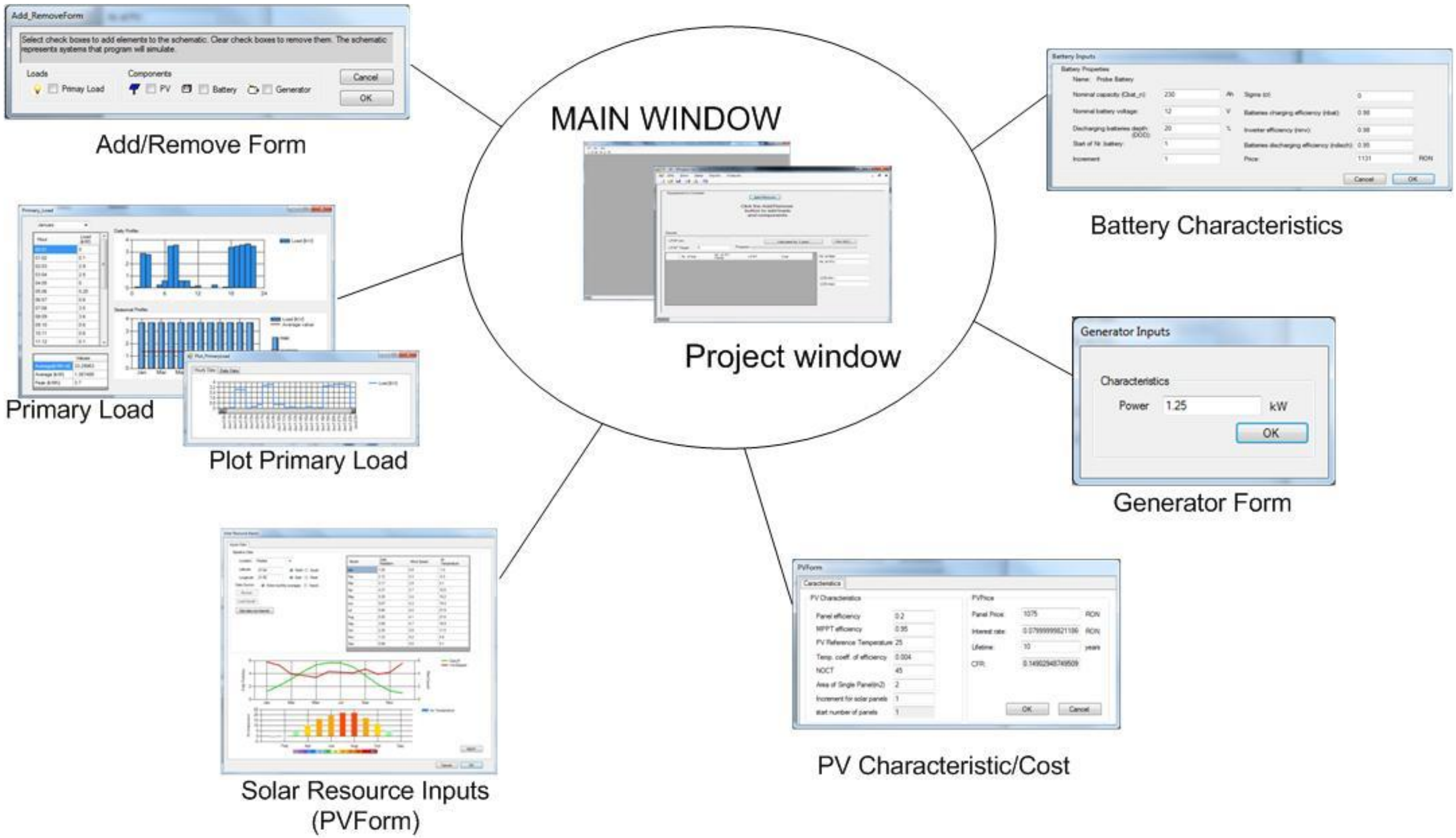

Fig. 1. Interface structure

2. PROGRAM IMPLEMENTATION

2.2. Project Form

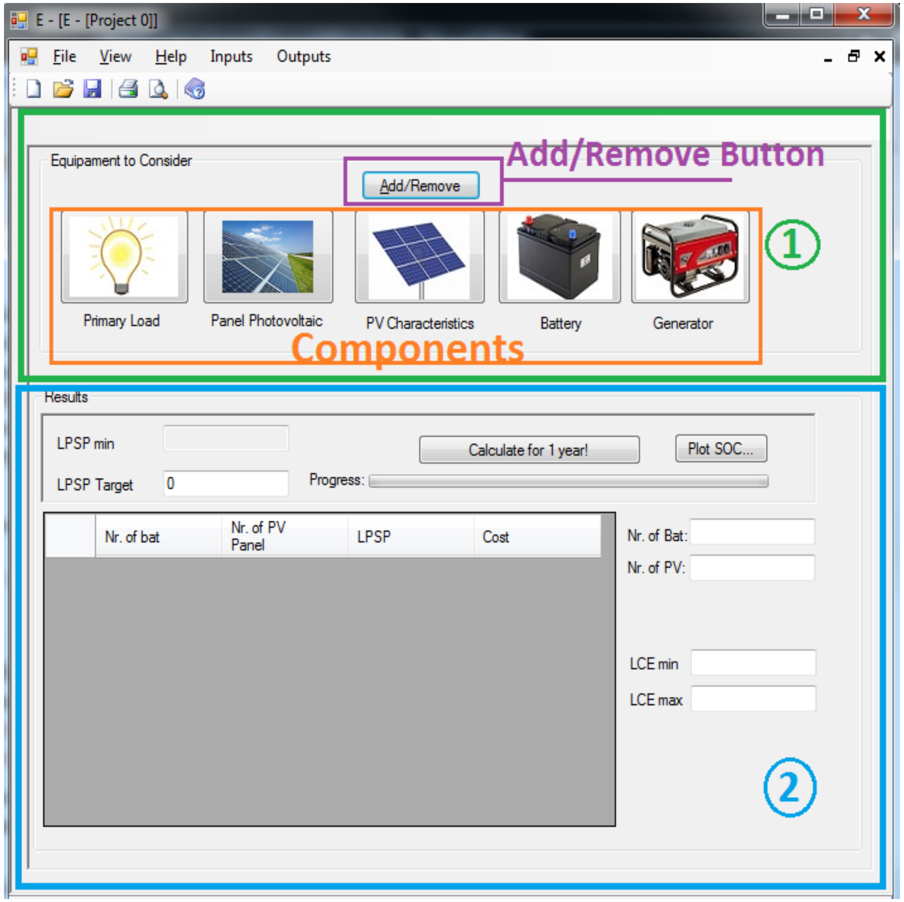

Fig. 2. Project Form

The first part contains only one button, the Add/Remove button at the moment of start. The components are added or deleted by this button.

The second part presents the results of the economic analysis.

2. PROGRAM IMPLEMENTATION

2.3. Add or remove components

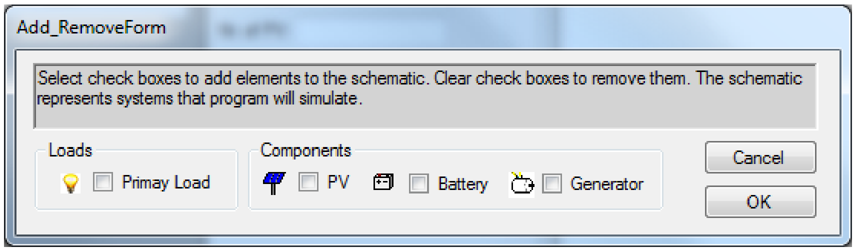

Fig. 3. Add/Remove Window

The components will be: primary load, photovoltaic panels, batteries and generators.

Fig. 4. Components

At the selection of every button, a new window becomes available: allowing the user to set the characteristics of the components.

2. PROGRAM IMPLEMENTATION

2.4. Load profile

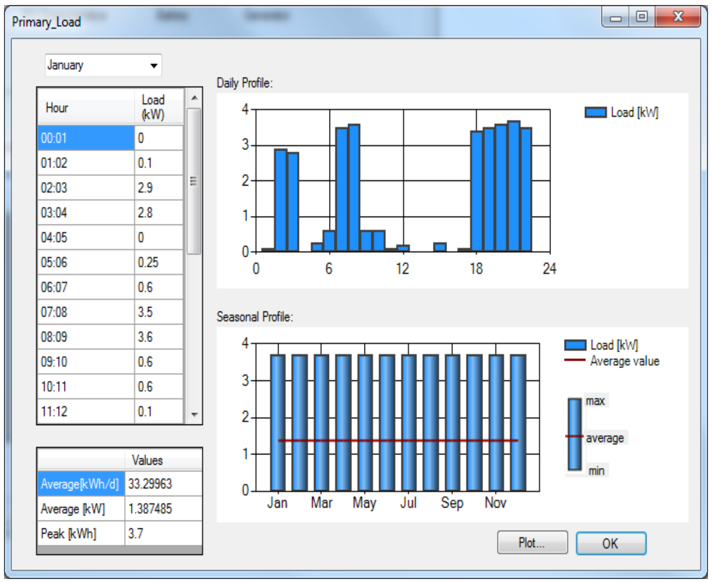

Fig. 5. Load Window

In the load table the user specifies their power consumption profile.

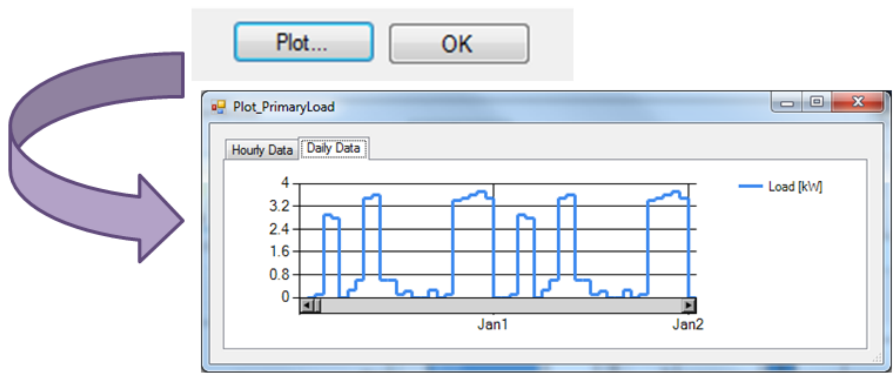

Fig. 6. Plot Load Profile

Clicking the Plot button, the data is represented in more detail.

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2. PROGRAM IMPLEMENTATION

2.5. Solar Resource Inputs

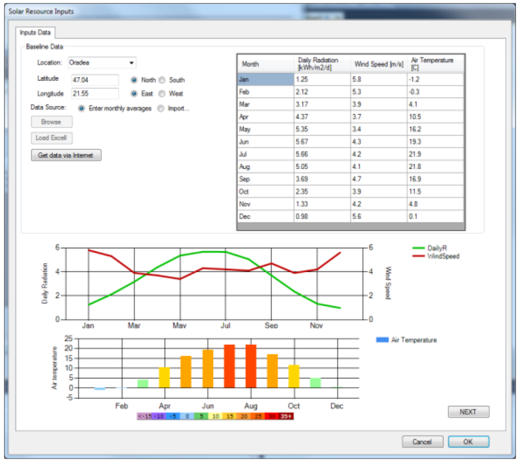
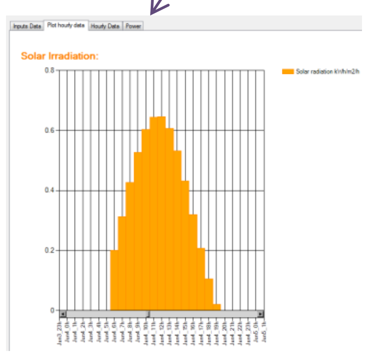


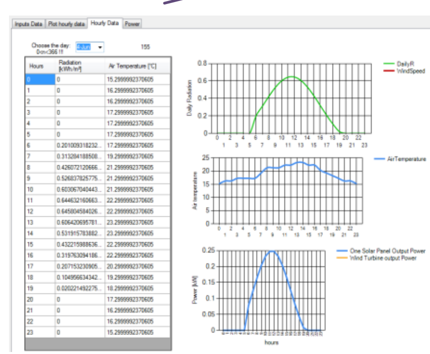
Fig. 5. Solar Resource Inputs Window

The city of Oradea was chosen for testing from the database. The monthly average value of the solar irradiation and temperature are represented on the figure 5.

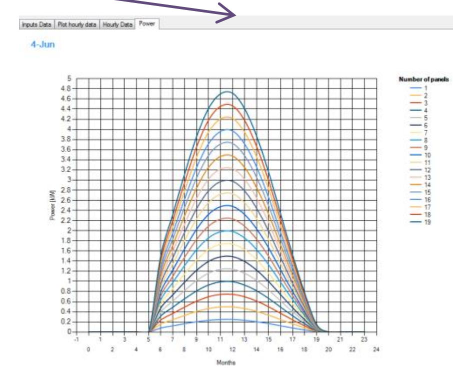
There is a possibility to analyze data in more detail pressing the NEXT button.



Plot Hourly Data tab



Daily data tab



Power tab

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2. PROGRAM IMPLEMENTATION

2.6. Hourly radiation prediction algorithm

The hourly global irradiation data is determined using:

$$r_t = \frac{G_t}{H} \quad (1)$$

Where:

- G_t - hourly global radiation, considered one period of years.
- H - measured monthly (mean daily global) average radiation
- r_t - hourly to daily radiation ratio

The value r_t can calculated using the following equation from Collares-Pereira and Rabl:

$$r_t = \frac{\Pi}{24} \cdot (a + b \cdot \cos \omega) \cdot \left(\frac{\cos \omega - \cos \omega s}{\sin \omega s - \frac{\Pi \cdot \omega s}{24} \cdot \cos \omega s} \right) \quad (2)$$

The coefficients a and b can be estimated by:

$$a = 0.409 + 0.5016 \cdot \sin(\omega s - 60)$$
$$b = 0.6609 + 0.4767 \cdot \sin(\omega s - 60) \quad (3)$$

Where:

- ω is the hour angle (in degrees – for the time in question)
- ω_s is the sunset hour angle: $$\cos \omega s = -\frac{\sin\phi \sin\delta}{\cos\phi \cos\delta} = -\tan\phi \tan\delta \quad (4)$$

$$\delta = 23.45 \cdot \sin\left(360 \cdot \frac{284 + n}{365}\right) \quad (5)$$

Where:

- φ – latitude
- δ - solar declination
- *n* - day of the year (from 1 to 365)

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2. PROGRAM IMPLEMENTATION

2.7. PV Characteristics

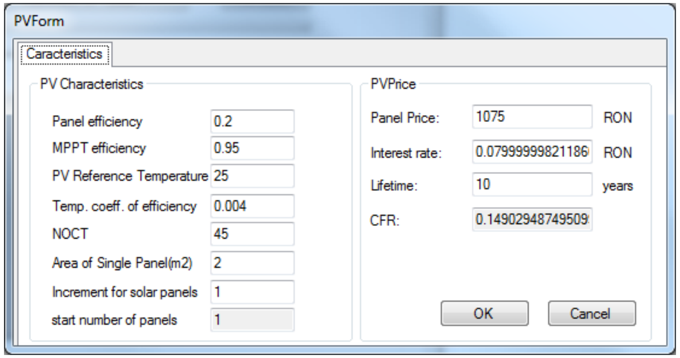

Fig.6. PV Characteristics Window

To calculate the power output of solar panels near the solar irradiation the user can enter the panel performances found in the datasheets: panel efficiency (η_r), MPPT efficiency (η_{ppt}), reference temperature (Tr), temperature coefficient (β_r) and nominal operating cell temperature (NOCT). Near the PV parameters the economic parameters can be introduced.

The next equation describes the power output of solar panels: $Ppv = \eta pvg \cdot N_{PV} \cdot Am \cdot Gt$ (6)

Where:

- η_{pvg} - instantaneous efficiency: $\eta pvg = \eta r \cdot \eta ppt \cdot [1 - \beta r(Tsp - Tr)]$ (7) $Tsp = Ta + Gt(\frac{NOCT - 20}{800})$ (8)
- A_m - surface area of PV generator
- G_t - solar incident radiation[W/m^2]
- N_{PV} - number of panels

2. PROGRAM IMPLEMENTATION

2.8. Geothermal energy settings

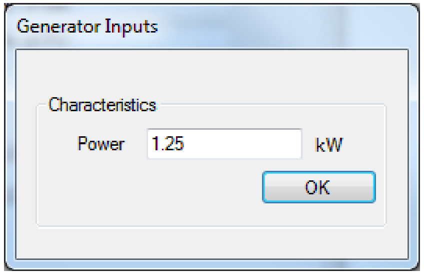

Fig.7. Geo Generator Window

You can enter the geothermal power value.

2.9. Storage Elements

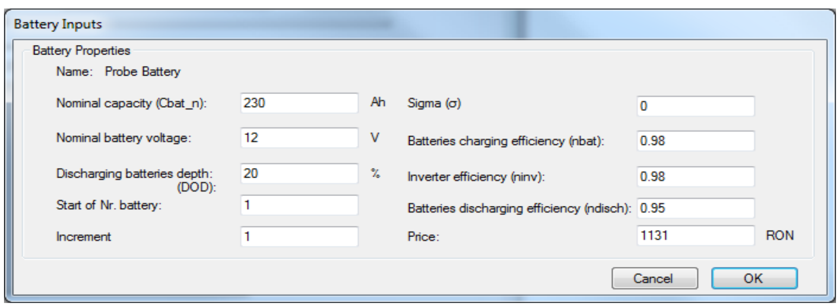

Fig.8. Batteries' Window

To determine the storage capacity of the system, the nominal capacity and the nominal battery voltage are needed.

Also, the parameters which describe the process of charging and discharging, the depth of discharge, the sigma and the efficiency parameters are required. The battery price is also introduced in this section.

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2.10. Storage model

Two different scenarios exist:

A. First scenario: $Egeo(t) \geq EL(t)$ → batteries in charging process

$$SOCbat(t) = SOCbat(t-1) + (Epv(t) + (Egeo(t) - EL(t)) \times \eta inv) \times nbat \quad (9)$$

B. Second scenario: $Egeo(t) < EL(t)$

B1. $Epv(t) \geq (EL(t) - Egeo(t)) / \eta inv$ → batteries in charging state: $SOCbat(t) = SOCbat(t-1) + (Epv(t) - (\frac{EL - Egeo}{\eta inv})) \times \eta bat$ (10)

B2. $Epv(t) < (EL(t) - Egeo(t)) / \eta inv$ → batteries in discharging state: $SOCbat(t) = SOCbat(t-1) + (Epv(t) - (\frac{EL(t) - Egeo(t)}{\eta inv})) \times \frac{1}{\eta disch}$ (11)

In all cases the state of batteries charging must satisfy the following requirement:

$$SOCbat\_min \leq SOCbat(t) \leq SOCbat\_max \quad (12)$$

In case B2. if the batteries cannot satisfy the load demand, the deficiency named LPS – Loss of Power Supply - can be calculated:

$$LPS(t) = (PL(t) - Pgeo(t)) \times \Delta t - \\ -(Ppv(t) \times \Delta t + SOCbat(t-1) - SOCbat\_min) \times \eta inv \quad (13)$$

Loss of power supply probability (LSPS) can be considered as a ratio between the sum of loss of power supply and the total amount of load during the one year period:

$$LPSP = \sum_{t=1}^{T} LPS(t) / \sum_{t=1}^{T} EL(t) \quad (14)$$

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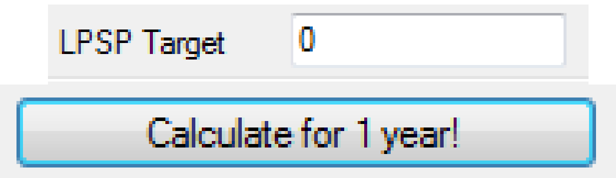
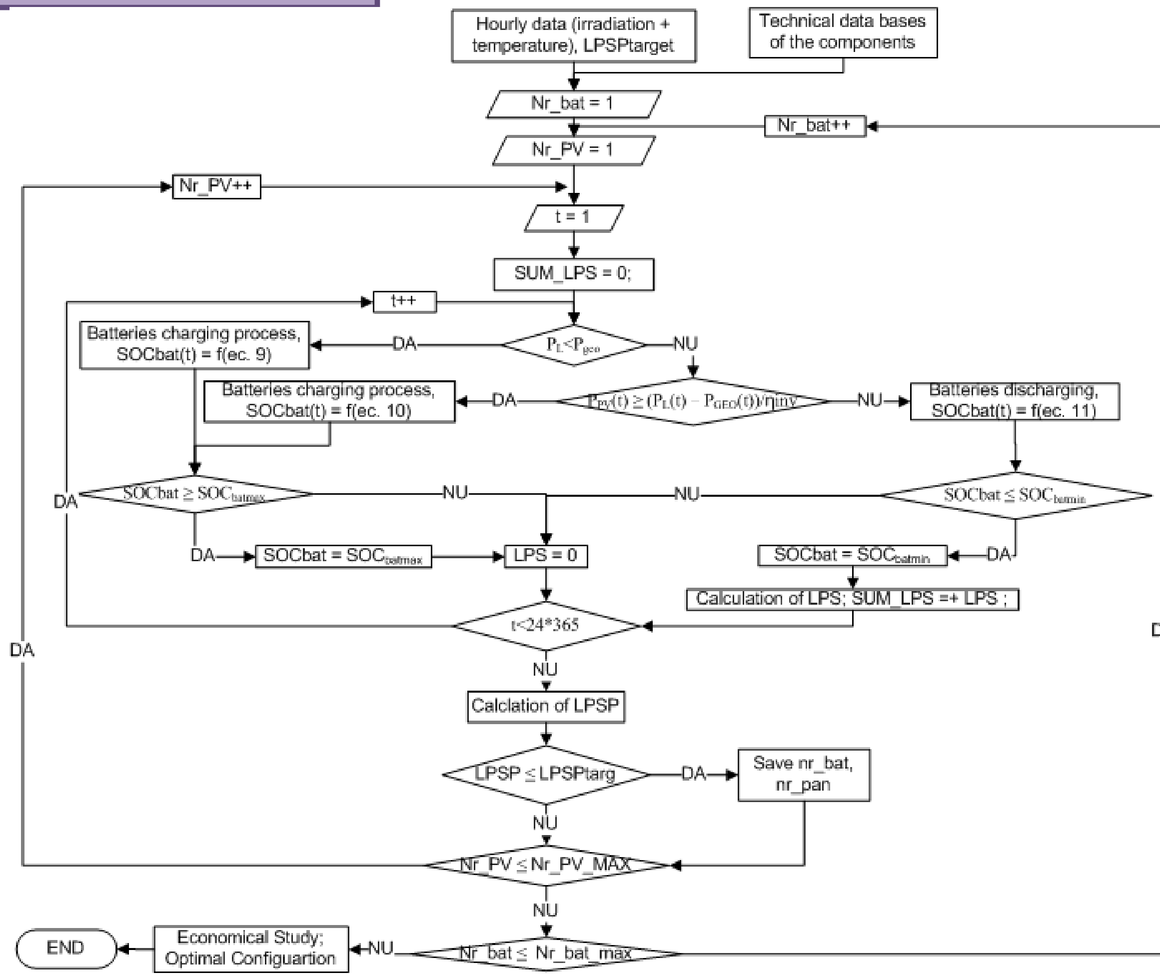
2.11. Optimal number Subroutine





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2.12. Economical Analysis

The levelized cost of energy is given by: $$LCE = \frac{CRF(i,n) \cdot TPV}{SUM\_EL} \quad (15)$$

- SUM_E_L is the yearly output of the load demand
- CRF is the capital recovery factor: $$CRF(i,n) = \frac{i \cdot (1+i)^n}{(1+i)^n - 1} \quad (16)$$

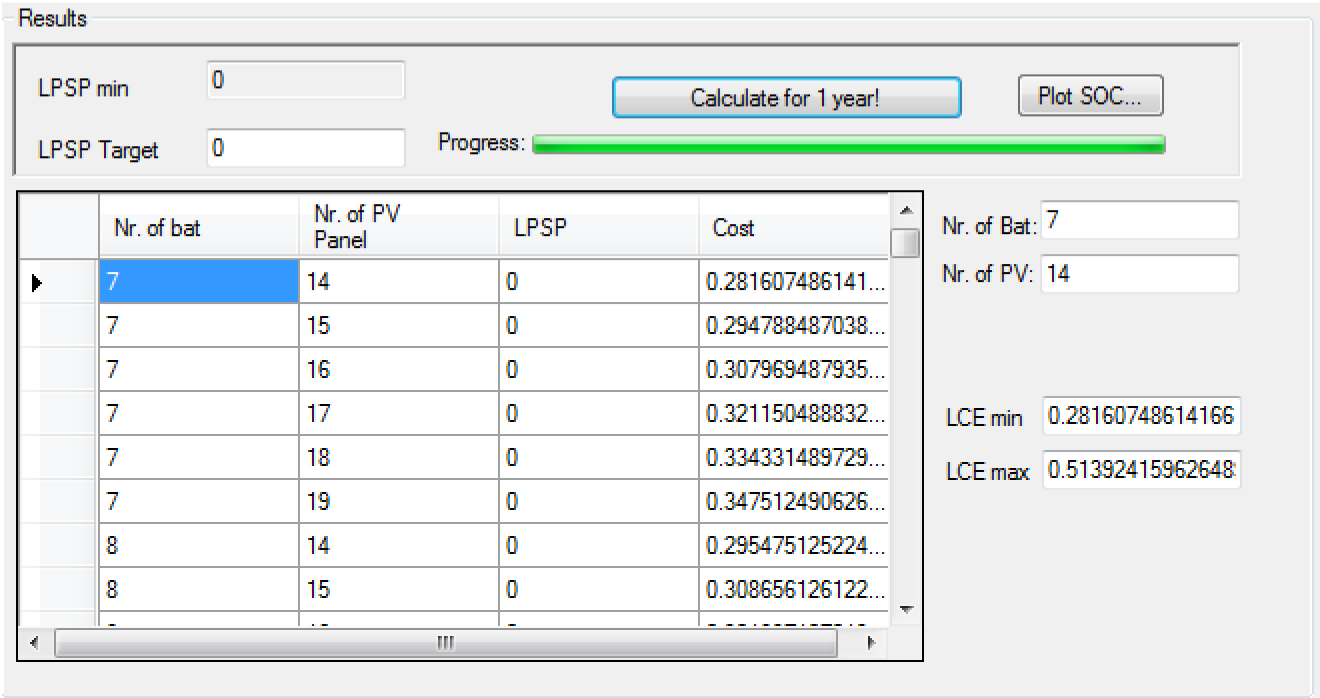
- TPV is the total present value of the actual cost of all system components

$$TPV = N_{PV} \times C_{pv} + N_{bat} \times C_{bat} \quad (17)$$

Where:

- i – appreciation of money in time
- n – the system life in years
- C_{pv}, C_{bat} – capital cost of the microgrid
- N_{pv}, N_{bat} – number of solar panels, respectively battery

3. RESULTS



	Nr. of bat	Nr. of PV Panel	LPSP	Cost
▶	7	14	0	0.281607486141...
	7	15	0	0.294788487038...
	7	16	0	0.307969487935...
	7	17	0	0.321150488832...
	7	18	0	0.334331489729...
	7	19	0	0.347512490626...
	8	14	0	0.295475125224...
	8	15	0	0.308656126122...

- It can be observed that LCE has a minimum point of 14 solar panels and 7 batteries.

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4. CONCLUSION

- This application is based on the hourly radiation prediction algorithm, on LPSP and LCE concepts. The lowest LCE suggests the optimal number of components.
- The results strongly depend on the cost of the components, their lifetimes, their characteristics, and also on the load profile and the meteorological characteristics.
- Through this application the user can change the location (setting the latitude and longitude data), modify the meteorological data, set the photovoltaic, geothermal and battery characteristics and can analyze different cases easily.
- With this program the data processing becomes practical, interactive and easy.

Thank you for your attention!

Any Questions?

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