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Original Research

Techno-economic optimization of solar energy-based electrification systems for remote islands

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Supplementary Materials

The following supplementary materials are available on the website of this paper:

Appendix 1. PV Panels Energy Yield Estimation
Appendix 2. Financial Evaluation of the Proposed Solutions

Appendix 1. PV Panels Energy Yield Estimation

Based on the analysis of [1] and [2] the power output "P(t)" of a PV installation vs. time may be estimated using the solar irradiance "G(t)" at the desired tilt and azimuth angle (based on measurements at horizontal plane) [3] and the ambient temperature "$\theta_a(t)$".

Accordingly, the PV modules temperature "θ_c" is estimated using Ross coefficient- equation (A1) and the analysis of [2] including the wind speed impact, as:

$$\theta_c = \theta_a + k \cdot G \tag{A1}$$

Using the solar irradiance and the PV-modules temperature the operational characteristics (current "I" and voltage "U") of the selected PV modules are estimated, using the (I-U) curves provided by the PV-modules manufacturer for different solar irradiance and cell temperature values.

Subsequently, the PV installation power output is estimated using equation (A2):

$$P(t)=U(t).I(t)\ (1-\varepsilon_{loss}) \tag{A2}$$

where "ε_{loss}" describes the power loss between the PV-cell output and the PV installation output, including cable loss, inverter loss, etc. Normally this factor takes values around 10–15%.

Finally, the energy yield of the PV installation for a given time period "Δt" is calculated as:

$$E_{\Delta t}=\int_{to}^{to+\Delta t} P(t).dt \tag{A3}$$

Appendix 2. Financial Evaluation of the Proposed Solutions

For the estimation of the NPV of the proposed PV-battery installation, one should take into account [1,4] the investment turnkey-cost "IC_o", the installation annual maintenance and operation cost "FC", the corresponding annual revenue "R", while the investment discount rate "i" is taken here equal to 5%. For the present analysis the total investment cost varies between 1.4 M€ and 2.7 M€, depending on system PV nominal power and storage capacity. The corresponding installation annual maintenance and operation cost is assumed equal to 1–2% of the investment cost, while the system batteries will be totally replaced every eight (8) years. Finally, the installation annual revenue (direct fuel savings) approach 370.000–450.000 €/yr.

In this context, the NPV of the PV-battery solution may be estimated using equation (B1), i.e.,

$$\mathrm{NPV} = \sum_{j=1}^{j=n} \frac{R_j - FC_j}{(1+i)^j} - IC_o \quad \text{(B1)}$$

where "n" is the service period of the installation.

The corresponding complete payback solution is calculated (given the value of the discount rate "i") by estimating the j = n* value where for first time the total revenue counterbalance the investment cost and the operational and maintenance cost at present values:

$$\mathrm{NPV}=0 \quad \text{(B2)}$$

The simple payback is estimated by assuming that the proposed analysis discount rate is zero (i.e., i=0%)

Finally, by solving equation (B3) for the entire service period of the installation "n" (e.g., n=20 years) one may estimate the "IRR" value of the investment, i.e.,

$$NPV = \sum_{j=1}^{j=n} \frac{R_j - FC_j}{(1+IRR)^j} - IC_o = 0 \quad \text{(B3)}$$

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