Contrastive techno-economic analysis concept for off-grid hybrid renewable electricity systems (OHRES)
Based on comparative case studies within Canada and Uganda

3rd International Hybrid Power Systems Workshop
Tenerife/Spain, 8 - 9 May 2018

Who we are...
Battery Technical Center
System Competence along the Value Chain
Cost-effective product design and production technologies

- Interdisciplinary cooperation of different KIT institutes
- R&D scope
  - High energy materials and compact cell designs
  - Modular battery designs
  - Optimized production processes
  - Storage systems design and analysis
The main vision for our study is to support the role of sustainable energy in providing energy access and help to end energy poverty worldwide \(^1\)\(^2\).

The research study is carried within the global initiative Affordable Energy for Humanity (AE4H)\(^2\).

- Energy access challenge includes a wide range of objectives which cannot be covered all in one.
Study scope and objectives

- **The lack of reliable data** related to system performance combined with economical analysis.
  - Due to the **absence of standardization**

- Our main focus: **techno-economic aspects**
  - Off-grid Hybrid Renewable Electrical Energy systems (OHRES)
  - How technical, economic "environmental & Social" affect economic feasibility, sustainability.

- **Comparative study based on contrastive case studies** in remote areas
  - Identifying the common problems and challenges
  - Propose possible generic approaches and solutions

Research overview and study scope

- **Case Studies**
  - Selection criteria
  - Overview and related general information
  - Load profile and energy demand

- **System techno-economic related aspects**
  - System design criteria and objectives
  - System topology and layout
  - Decision making methodology for technical aspects
  - Brief overview of the HKAS model
  - System monitoring and weather station (SMWS)

- **Uganda Case study system deployment**
  - Site visit and system phase (1) deployment
  - Major lessons learned and shared experiences
### Summary of case-studies selection criteria

**Case-studies overview**

<table>
<thead>
<tr>
<th>General Info</th>
<th>Access to electricity (% of population)</th>
</tr>
</thead>
</table>

**World Bank, Sustainable Energy**


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### Case-studies overview

#### Load survey and distribution - The case of Uganda

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Watts</th>
<th>Number</th>
<th>Total Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp AC 220V</td>
<td>5</td>
<td>82</td>
<td>4</td>
<td>410</td>
</tr>
<tr>
<td>Computer AC 220V</td>
<td>40</td>
<td>30</td>
<td>3</td>
<td>1200</td>
</tr>
<tr>
<td>Printer AC 220V</td>
<td>500</td>
<td>1</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>Projector / TV AC 220V</td>
<td>300</td>
<td>2</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>Standing fan AC 220V</td>
<td>30</td>
<td>5</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>SMWS DC 24/12 V</td>
<td>10</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Pump AC 220V</td>
<td>1200</td>
<td>1</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>Mobile charger AC 220V</td>
<td>220</td>
<td>1</td>
<td>220</td>
<td></td>
</tr>
</tbody>
</table>

**Load profile and energy demand**

**Uganda**
- During **week-days** the total connected load (TCL) peak is up to **2500 Watt**.
- During the **weekend** the TCL peak reaches **2075 Watt**.

**Canada**
- Total connected loads (TCL) possible peak demand is up to **2200 Watt**.

**Both Case-studies**
- AC and DC loads, but AC loads are dominant.
- **Energy consumption**
  - (1319 - 2121 kWh/year)
- Within tier-4 level of access in the multi-tier framework for household energy based on the World Bank recommendations [6]

**Case-studies overview**

**Load profile and energy demand**

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System techno-economic related aspects

Design criteria and objectives

- Each off-grid location can be unique and represents its own requirements.
- It is hard to select a major criteria for the system design which can fulfill the needs of all off-grid electrical energy supply problems.
- Criteria of the system design have a major influence on the technical and economical related aspects of the end product.

Economically feasible
User-friendly (easy use interface and remote access)
Reliably and robust
Simple system architecture
Highly safe (mis-use proof)
System techno-economic related aspects

**Layout and topology**

- Using the state-of-the-art components for each of our system elements.
- Developing and testing together with industrial partners new technical concepts,
  especially in the energy storage and system remote monitoring and control parts.

Decision making methodology for system technical aspects

- Can take advantage of future trend of development for the storage market.
- Compatibility with commonly used commercial available low loss storage systems.
- Using of cheaper cables with small cross section.
- Off-grid components can handle more power in the same product category.
- Availability of a range of commercial off-grid component in the voltage range.

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System techno-economic related aspects

Brief overview of the HMGS techno-economic model

- Model development is based on the work of [18] developed originally for the assessment of standalone systems.
  - New boundaries, side conditions
  - New optimization algorithm and techno-economic calculations are added.

- Finding the best composition of generation units and optimum energy storage operation mode under the given optimization goals.

The optimization aims

- Minimize the loss of power supply probability (LPSP)
- Minimize the levelized cost of electricity (LCOE)
- Increase the RE share

C-DEEPSO (Canonical Particle Swarm Optimization Algorithm)

- New population-based method built upon swarm intelligence and differential evolutionary technique.
- Used as a solving algorithm instead of an original particle swarm optimization due to a higher robustness of results.

Detailed information about C-DEEPSO and HMGS in [18], [19], [20] and [21]

Homer energy [22] is used beside HMGS

- OHRES feasibility analysis and system sizing optimization.

Summary HMGS vs Homer Energy

- System techno-economic related aspects
- Homer energy [22] is used beside HMGS
- OHRES feasibility analysis and system sizing optimization.
Remote system monitoring and weather station (SMWS)

Main Components:
- Self-powered commercial weather station
- Hall effect sensors (voltage / current measurement)
- Controller and data acquisition unit
- GSM Modem

Current sampling rate 15 sec -> Can go up to 1 Sec
Data default refresh rate -> 15 min
GSM or internet based data communication
RS485 Modbus communication & CAN bus integration ability

Agenda Core Topics

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Uganda Case study system deployment
- Site visit and System phase(1) deployment
- Major lessons learned and shared experiences
UGANDA CASE-STUDY

Major highlights on some of the practical learned lessons

• Important pre-requisite
• Pre-commissioning and cold-run
  - In a controlled environment
  - Test as much as possible prior to shipment
• Not possible to perform pre-commissioning/testing for all system components and scenarios.
  • Some of the pre-tested components can represent a challenge >> GSM modem.
• No clear risk mitigation methodologies available for such risk sources due to the general lack of standardization.
  • Some components would still represent a technical challenge
• System logistics could be an under-estimated aspect in theoretical evaluations
  - Due to the lack of practical experience in most of the research work done.
  • Play a major role in the system deployment feasibility.
  • Represent a major influence on the economics of the off-grid system.
• Handling logistics in an effective way
  • Represents the main access point to the targeted local community.
  • Local coordination roles and support activities on the ground
  • One of the common partner types in developing countries are NGOs.
  • If the project represents one of the core needs or activities of the NGO the reflection on results will be remarkable
• Having the right local main project partner
  • Local communities are either a support or a risk source for off-grid projects.
  • Involvement of the local community in early stages of project lifecycle.
  • Should be done with certainly respected hierarchy
• Local community involvement

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Agenda Core Topics

- Study outlook
  - A site assessment for the Canada case-study is planned.
  - The pre-commissioning and lab testing of the first complete prototype including the hybrid storage system and the SMWS
  - The deployment of the two OHRES in case-study locations

- Developing a data analysis platform using Python
- Optimization of the HMGS techno-economic used calculation models
- Testing other MODELLS and TOOLS for our case-Studies
Resources & References


