Off-grid Hybrid renewable Electricity systems (OHRES) deployment, techno-economic modeling and system data analysis platform using hybrid battery storage.

Shared experience from first case-study system deployment
in Nemiah Valley, BC, Canada

Mohamed M.Elkadragy
Mughees Iqbal[1], Mert Alici[1], Manuel Baumann[1], Jatin Natwani[2], Joachim Knebel[1], and Marc Hiller[1]
Karlsruhe Institute of Technology (KIT)[1]
Institute of Electrical Engineering (ETI) – Battery Technical Center
University of Waterloo[2]

Hermann-von-Helmholtz-Platz 1, 76344, Eggenstein-Leopoldshafen, Germany.
Phone: +49 721 608 28323
E-mail: mohamed.elkadragy@kit.edu
Website: www.batterietechnikum.kit.edu/english/
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Offgrid hybrid renewable electricity systems (OHRES) is a major important player in the energy access global challenge. What we are investigating is how technical, economic, and environmental contexts influence the economic feasibility and sustainability of OHRES systems. Our methodology to achieve such objective is through carrying out a contrastive techno-economic analysis and system design optimization of two similar wind/solar OHRES systems installed in case-study locations with very different climatic and economic conditions - Canada and Uganda. These projects are carried out as part of the AE4H[1] global initiative.

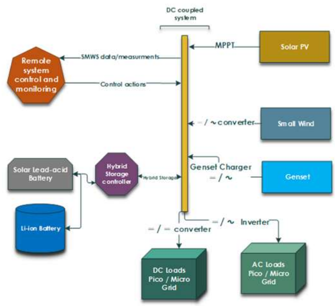

Figure 8 OHRES topology and main system components

1. OHRES first case-study system deployment in Canada

In this publication (which can be considered as following-up publication to our poster in the previous energy access conference), we will share the latest status of our first OHRES deployment in a household located in Nemiah Valley, BC, Canada. The hybrid system includes solar PV, small wind turbines as main renewable energy sources. In addition to dual-fuel genset as backup unit, and Hybrid lead-acid & Lithium-Ion (Li-ion) battery storage system with 48V DC coupling, which represents a unique and innovative

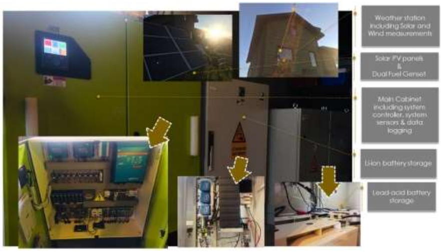

Figure 9 OHRES in Canada household case-study - System on ground commissioning

system structure as shown in figure 1. The system includes also system monitoring and weather station (SMWS), with full system remote monitoring and the ability of system selected components remote control. The case-study household in Canada is currently fully running on the OHRES as shown in figure 2, after one year of lab testing.

We will highlight the technical and economic benefit of having a hybrid lead-acid + Li-ion battery storage system for such application, using detailed techno-economic modeling results based on real system deployment costs for the Canada case study. Example of the technical joint force characteristics of both batteries can be seen in figure

2. Offgrid Systems Data Analysis Platform (OSDAP)

The second aspect is our OSDAP (figure 3), which is a Python-based tool developed to carry out performance analysis tasks on the OHRES operation data. This tool has been developed for one day or long-term performance analysis of PV, energy storage unit and overall system performance. The tool has been using the data generated from the already running OHRES in Canada, and it has been developed in a generic architecture so that it can also perform the performance analysis tasks on both case-studies OHRES, once they are deployed and starts operating.

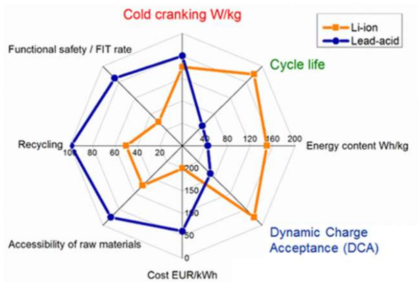

Figure 10 Li-ion and Lead-acid storages general joint forces characteristics[2].

An artificial neural networks based solar irradiance forecasting model has been developed to make one-hour ahead and 24-hours ahead solar irradiance forecasts. Long-short term memory (LSTM) model takes historical weather data from our weather station installed at the case study location in Canada and it yields one-hour ahead irradiance forecasts with RMSE value between 23 and 80, correlation coefficient range between 95% and 99%.

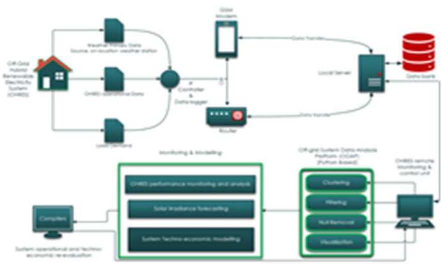

Figure 11 OSDAP updated functionality diagram

3. Hybrid Off-grid Techno-economic Model (HOTEM)

Third and last part of our publication is HOTEM. The Matlab based platform will be used to achieve the optimization goals by applying the Canonical Particle Swarm Optimization Algorithm (C-DEEPSO) which is built on swarm intelligent and differential evolutionary techniques that aim to finds the best composition of generation units and optimum energy storage operation mode [3]. C-DEEPSO will follow the techno-economic model towards the following optimization goals:

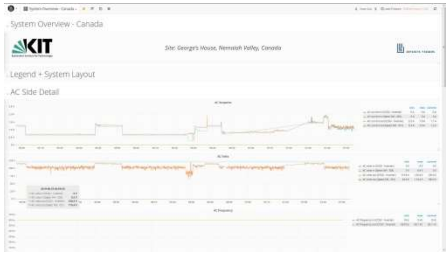

Figure 12 Remote data monitoring online platform example for Canada OHRES

- Minimum Levelized Cost of Electricity (LCOE)
- Minimum Loss of Power Supply Probability (LPSP)
- A maximum Renewable Energy Factor (RE_Factor)

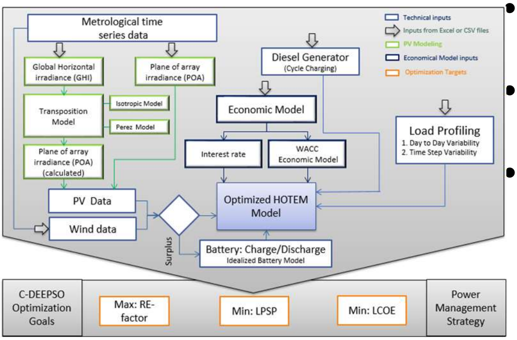

Figure 13 HOTEM model topology and structure

References

[1] Affordable Energy for Humanity (AE4H), OHRES project webpage: https://ae4h.org/projects/ohres

[2] Techreport Controls, Johnson: Impact of CO2 Emission Targets on Battery Technologies, 2018.

[3] Carolina Marcelino, Manuel Baumann, Leonel Carvalho, Nelson Chibeles- Martins, Marcel Weil, Paulo Almeida & Elizabeth Wanner (2019): A combined optimization and decision-making approach for battery-supported HMGS, Journal of the Operational Research. Society, DOI: 10.1080/01605682.2019.1582590