Institute of Electrical Engineering (ETI)
Battery Technical Center (BATEC)

Off-Grid Hybrid Renewable Electricity System (OHRES) techno-economic assessment, system size optimization and design

Based on comparative case-studies in Uganda and Canada

Mohamed M. Elkadragy[1], Manuel Baumann[2], Ahmed Alsersy[1], Nigel Moore[3] , Marcel Weil[2], Nicolaus Lemmertz[1], Marc Hiller[4]

Electrification of geographically remote communities is particularly challenging. These communities exist in both the developed and developing world, with different economic development contexts within which electrification must occur. One of the main obstacles for accelerated expansion of off-grid energy systems is the lack of reliable data relating to system performance combined with economic impacts. This is in large part due to the absence of standardization in technical and economic analyses. The study is carried out within the global initiative Affordable Energy for Humanity (AE4H)[1].

Objective and Methodology

- **The Research objective** is to understand how the technical, economic (including social), and environmental context in which an **Off-grid Hybrid Renewable Electricity system (OHRES)** as represented in figure (1) is deployed affects its economic feasibility and sustainability.
- Our research compares an OHRES deployed in two case studies with **contrastive economic and environmental conditions.** The selected locations are in **Canada (British Columbia) and Sub-Saharan Africa (Uganda)**[2]. Both Case-studies were selected taking into account the commonalities between sites regarding technical performance specifications such as expected peak-loads range (2200 to 2500 Watt) and energy consumption tier (tier(4):1319-2121 kWh/year[3]).
- OHRES will be installed in each location combined with an off-grid remote **System Monitoring and Weather Station (SMWS)** as in figure (2).
- A semi-identical system design is applied by using similar technologies with many common components for both case-studies. This allows us to carry out a **contrastive and reflective system analysis**.

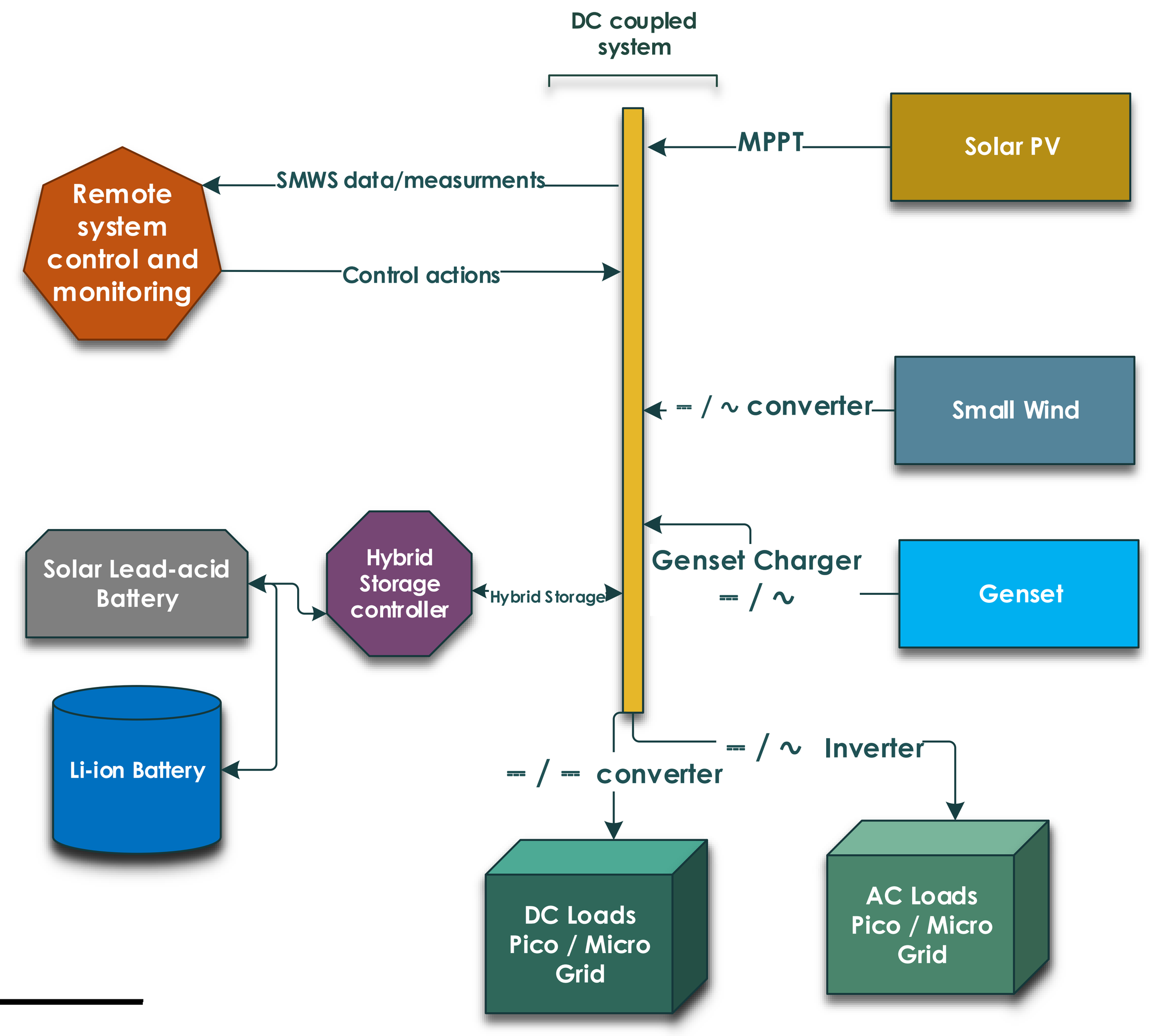

Figure 1: OHRES topology and components layout

OHRES techno-economic modeling and data analysis platform

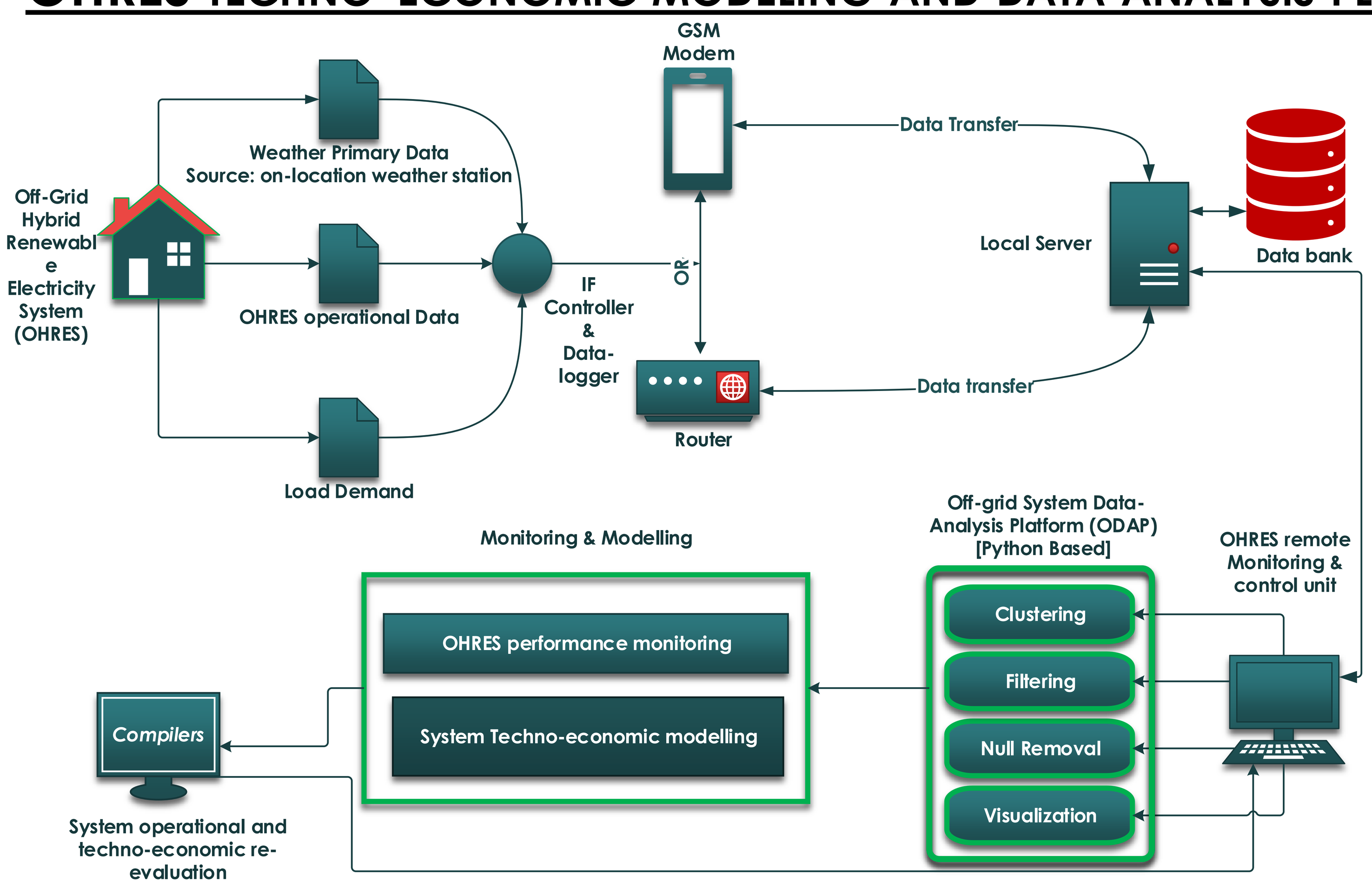

Figure 3: OSDAP architecture

- The role of the **off-grid system data analysis platform (OSDAP)** illustrated in figure (3) is to analyze the primary data generated through the OHRES System monitoring and weather station (SMWS).
- The Python-based platform analyzes the weather data, field system measured values and system components generated data, through applying handling techniques as data clustering, filtering, null elimination, and visualization.

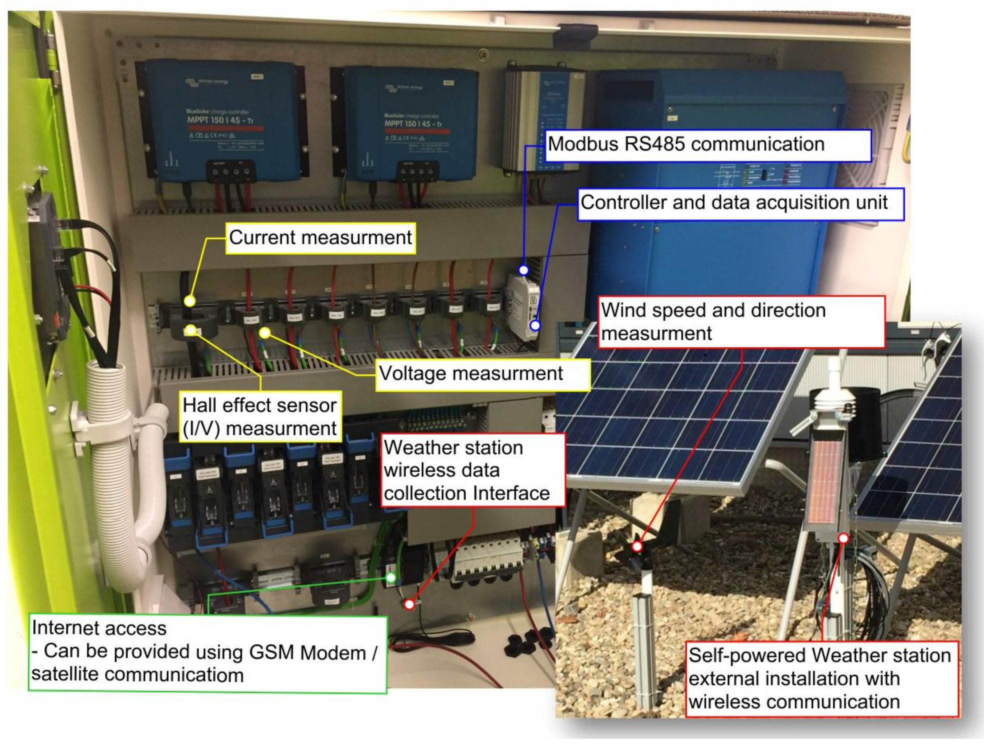

Figure 2: OHRES with Integrated System Monitoring and Weather Station (SMWS).

System Sizing and Techno-economic Modelling

- OHRES feasibility analysis and system sizing optimization is done using **Homer energy**.
- The internally developed **Hybrid Micro Grid Systems (HMGS)** [4] techno-economic assessment model is planned to be optimized for the techno-economic analysis of the OHRES.

Preliminary Results for the OHRES Dynamic Running test

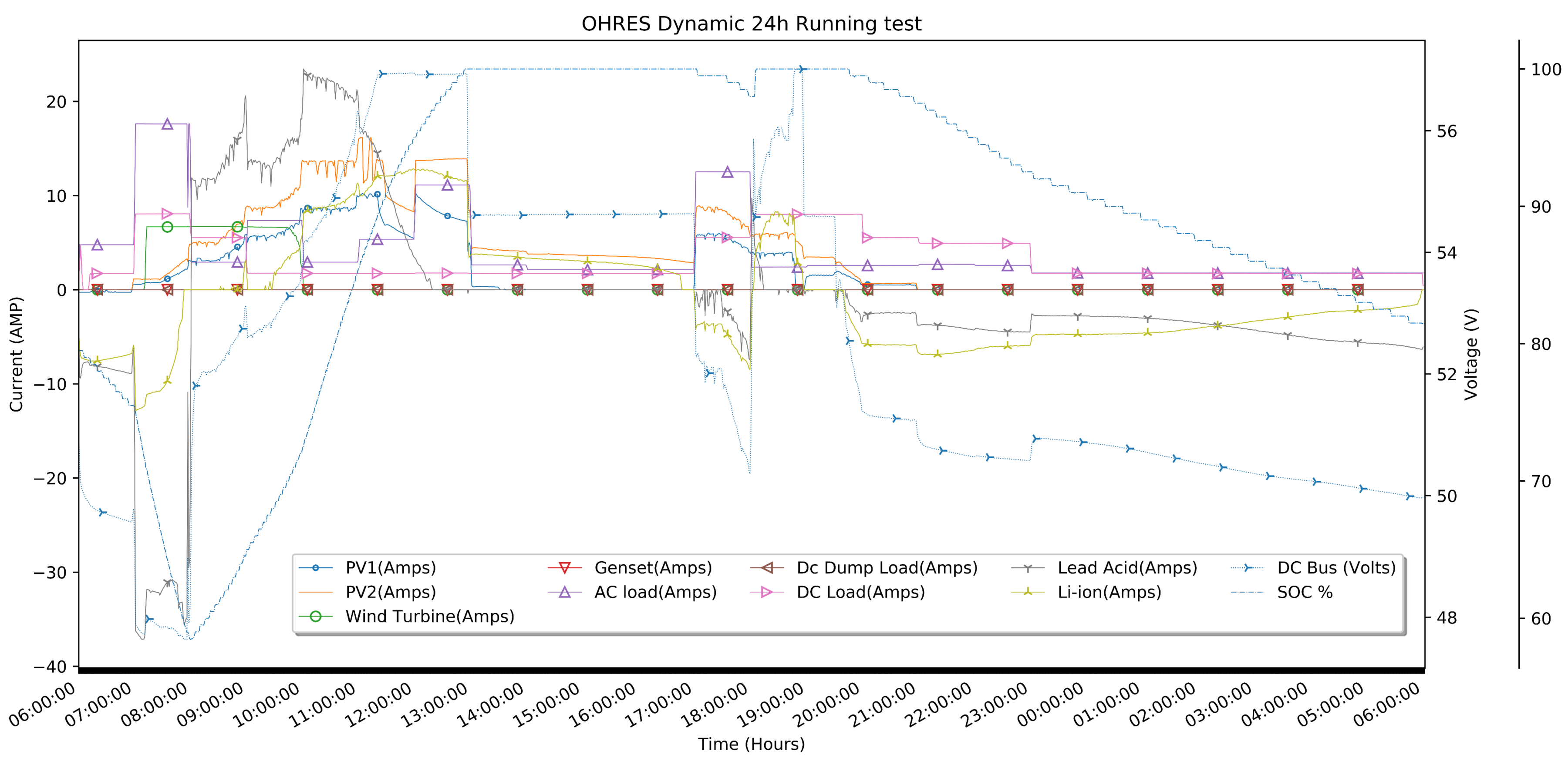

Figure 4: OHRES dynamic 24h dunning test. Test is done continually using PV and wind programmable simulators with the Canada case-study location resources solar and wind data for an average sunny summer day. Genset simulator is not used in that test, so a loss of load is allowed. Test start at 06:00 with a hybrid battery SOC of about 80%. The load curve used is the Total Connected Loads (TCL) profile.

Conclusion and Outlook

- The comparative techno-economic assessment for the case-studies in Canada and Uganda will provide a clear understanding for OHRES behavior in two extreme contrastive contexts. This will generate a precise understanding for how the OHRES economics are affected by technical and environmental related aspects.
- OHRES test is done using the load-curve and location data from the Canada case study. Results shows that the system dynamic behavior is stable. The hybrid storage works in good harmony with the load demand. In order to reduce the loss of load probability (LOLP) a genset is needed, even in a sunny day.
- The research project support the deployment of such systems not only in similar environments as the ones taken within the research scope, but also any other location within the extreme boundary conditions of our study, which can be theoretically considered for the whole world.

Bibliography

[1] Affordable Energy For Humanity (AE4H), global initiative. [Online]. Available: www.ae4h.org
[2] **M. Elkadragy**, M. Baumann, N. Moore, M. Weil, N. Lemmertz, M. Hiller. "Contrastive Techno-Economic Analysis Concept for Off-Grid Hybrid Renewable Electricity Systems – Based on Comparative Case Studies within Canada and Uganda," 3rd International Hybrid Power Systems Workshop, 2018. [Online]. Available: http://hybridpowersystems.org/wp-content/uploads/sites/9/2018/05/5A_4_TENE18_012_paper_Elkadragy_MohamedM.pdf
[3] F. F. Nerini, O. Broad, D. Mentis, M. Welsch, M. Bazilian, and M. Howells, "A cost comparison of technology approaches for improving access to electricity services," Energy, vol. 95, pp. 255–265, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.energy.2015.11.068
[4] Marcelino, C.; Almeida, P.; Wanner, E.; Baumann, M.; Weil, M.; Carvalho, L.; Miranda, V. Solving security constrained optimal power flow problems: A hybrid evolutionary approach. Applied Intelligence (2018), S. 1-19, publ. online, DOI: 10.1007/s10489-018-1167-5

1)Karlsruhe Institute of Technology (KIT), Battery Technical Center (BTC), Institute of Electrical Engineering (ETI).
2)Karlsruhe Institute of Technology (KIT), Institute for Technology Assessment and Systems Analyses (ITAS).
3)University of Waterloo, Waterloo Institute for Sustainable Energy (WISE).
4)Karlsruhe Institute of Technology (KIT), Institute of Electrical Engineering (ETI).
Corresponding Email: Mohamed.Elkadragy@kit.edu

Elektrotechnisches Institut