Integrating Hybrid Off-grid Systems with Battery Storage: Key Performance Indicators

U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

efacec

Luís Miguel Cruz da Costa

Master of Science in Electrical and Computers Engineering

Introduction

The high generation costs of off-grid systems and their large greenhouse gas emissions led to the need to integrate renewable energy sources into these electric grids. The generation from renewable energy sources has low operational costs and has few or zero greenhouse gas emissions but imposes some challenges that the system operator must address, such as intermittence, limited predictability and controllability. The integration of energy storage systems into the isolated grid allows increasing the integration of production based on renewable energy sources, enhancing the value of the grid assets and increasing the efficiency and flexibility of the grid.

This work proposes a set of Key Performance Indicators (KPIs) to assess the integration of hybrid off-grid systems with Battery Energy Storage Systems (BESS). Furthermore, considering these KPIs, a multi-stage methodology is developed, consisted of day-ahead planning of operation and intra-day dispatch, in order to reduce the Operational Expenditure (OPEX) of off-grid systems and maximize the share of Renewable Energy Sources (RES) in the electrical grid.

Methodology

Two sets of KPIs have been developed. The first set are the Operational KPIs and these KPIs aim to participate in the operation strategy of the microgrid system, they perform as monitored variables, and determine whether the system is working as expected relative to its mandate or whether it should adapt its behavior.

The second set are the Planning KPIs and these KPIs aim to assess the impact of the BESS in the microgrid at the BESS's End of Life. These KPIs enable the decision maker to assess the technical and economic viability of integrating the BESS in the microgrid.

The developed methodology, presented in Figure 1, aims to perform the day-ahead planning of operation and the intra-day dispatch for the generating and energy storage resources in the microgrid.

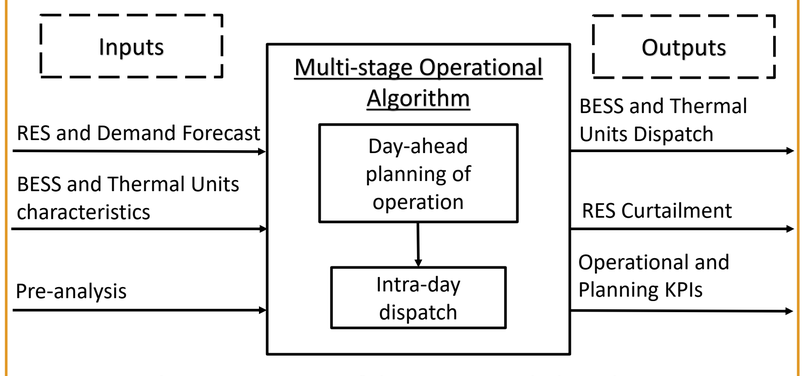

Figure 1 Overview of the Operational Algorithm.

Results

The developed methodology is assessed and validated on a case study of a real Island grid with renewable energy sources, considering a planning horizon of 10 years.

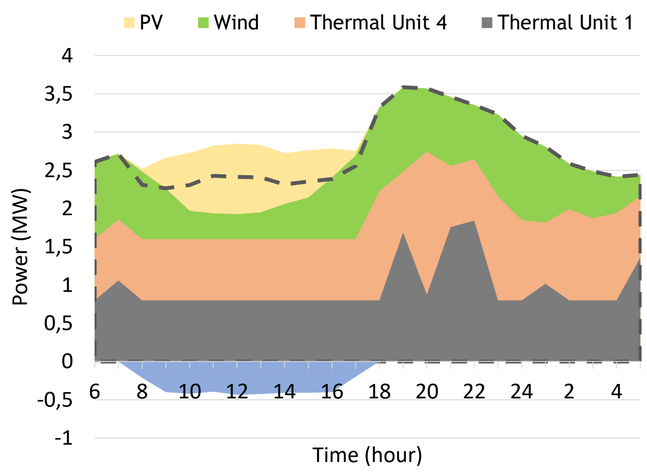

Figure 2 Day-ahead planning of the generating system without BESS.

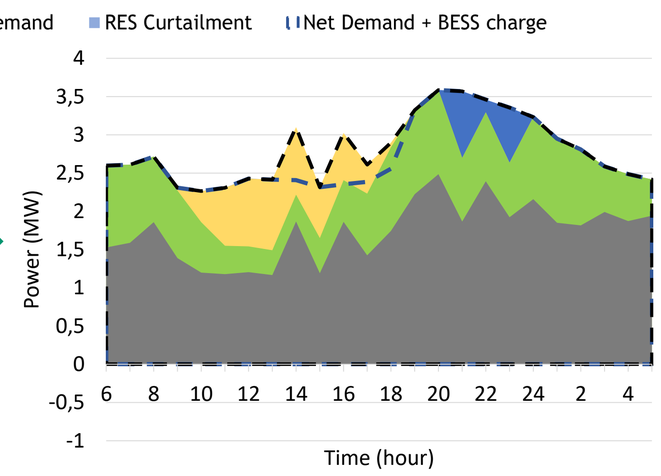

Figure 3 Day-ahead planning of the generating system without BESS.

With BESS → · Energy Time-Shift · Increased Flexibility of the Conventional Generation → Minimized RES Curtailed

Operational KPIs	
Renewable Curtailment Avoidance ($MWh_{integrated}/MWh_{excess}$)	1
Average Cost Reduction (€/hour)	38,27
Emissions Cost Reduction (€/day)	13,54
Cycle Benefits (€/day)	1 035,25
State of Health (%)	95,9

Table 1 Operational KPIs results.

Planning KPIs	
Levelized Cost Of Energy (€/kWh)	0,169
Levelized Cost Of Storage (€/kWh)	0,918
Levelized Benefits Of Storage (€/kWh)	1,152
Net Present Value (€)	417 954
Payback Time	8 year

↓1,23%

Table 2 Planning KPIs results.

The KPI RCA has the maximum possible value because all the renewable energy excesses in the off-grid system is integrated.

The cycles are very profitable economically, which makes KPI CB a positive value.

The improvement of LCOE may represent a reduction in the cost to be paid by end consumers.

The effective economic benefit of the BESS is the difference between the LBOS and the LCOS, which is 0,234€ for each kWh injected.

Conclusions

The developed multi-stage methodology addresses the variability and limited predictability of RES enabling a reduction of operational costs and CO_2 emissions.

Integration of BESS in off-grid systems provides technical improvement in the conventional generation system, particularly with the accommodation of renewable energy sources.

In off-grid systems with relatively low installed capacity of RES, the performance of cycles is quite reduced, however, the provision of primary spinning reserve results in economic benefits.

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