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Techno-economic HESS planning for the Marwell based standalone EV charging demonstrator

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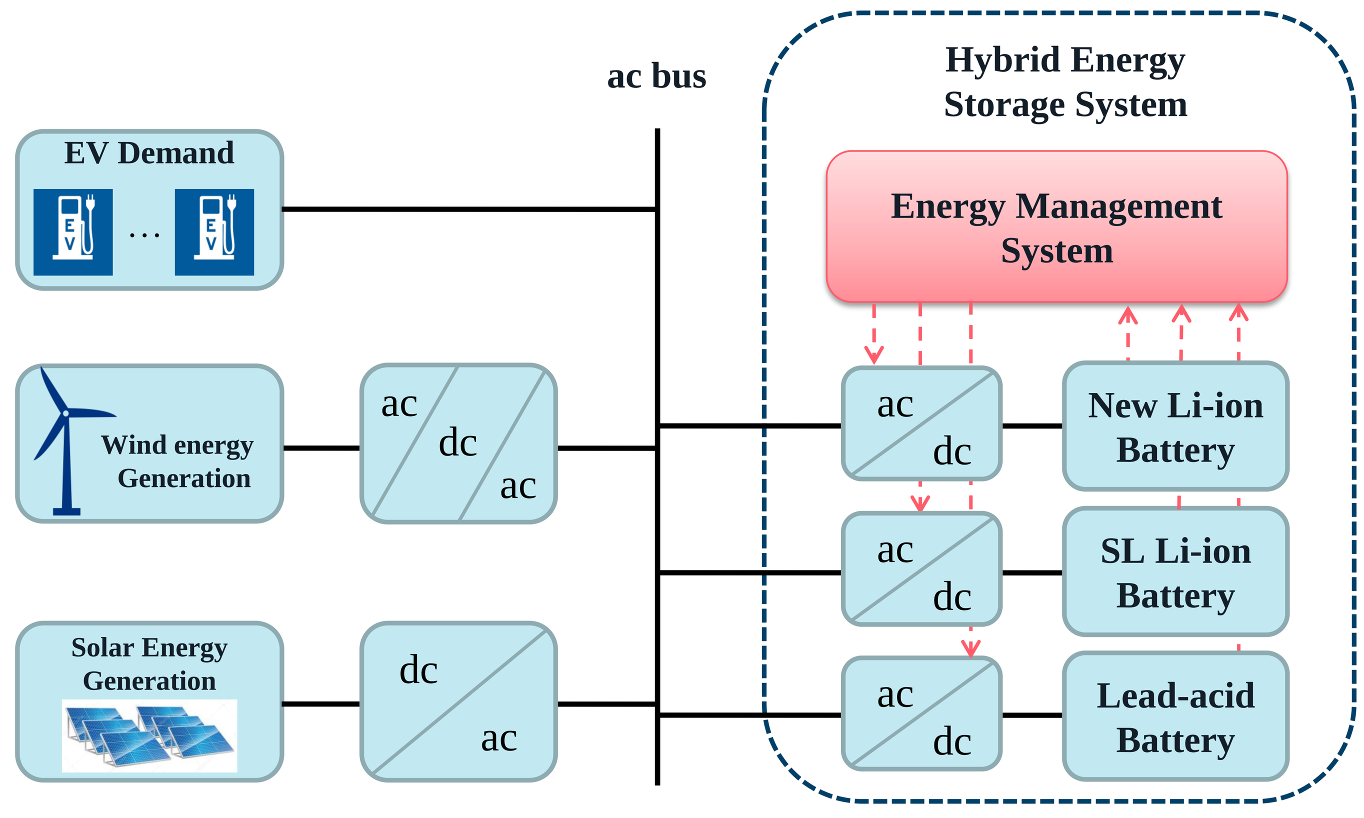
Abstract

- Techno-economic planning based on a sensitivity analysis approach to a hybrid energy storage system (HESS) for the Marwell zoo is investigated
- A power sharing-based energy management system (EMS), utilising SoC, DoD, and c-rate of the component ESSs in the HESS is described.
- The modified cost of energy is used as a techno-economic measure to compare different plans, where the present value of energy storage systems (ESSs) and the virtual cost of unmet energy of the electric vehicle (EV) charging station are considered.

The studied EV charging microgrid and HESS structure



SL: Second-life

Simulation data and feasible approaches

1 WT: 6 kW rated power used at 20 m hub height

60 PV panel: each 405 W, 1.95 m2, 20 %

EV load: Predicting EV increase for next 10 years

HESS: A combination of a new Li-ion, a second-life Li-ion, and a Lead-acid ESS

New modular Li-ion battery pack: 20-100 SOC, max c-rate=1

Second-life modular Li-ion battery pack: 20-80 SOC, max c-rate=1

New modular Lead-acid battery pack: 50-100 SOC, max c-rate=0.6

EMS: Power sharing-based EMS

Charging according to SOC, nominal capacity, and c-rate

Discharging according to DOD, nominal capacity, and c-rate

ESS cycle and calendar ageing model parameters

	New Li-ion ESS	Second-life Li-ion ESS	New Lead-acid ESS
SOH loss per 1000 cycles (%)	4.5	4.5	61.5
SOH calendar loss per month (%)	0.125	0.125	0.5
End of life (%)	40	40	60

Each plan: Simulating the Marwell system (a combination of WT, PV, ESS, and EV load) for ten years (2013-2022) incl. technical and economic models in MATLAB and Simulink

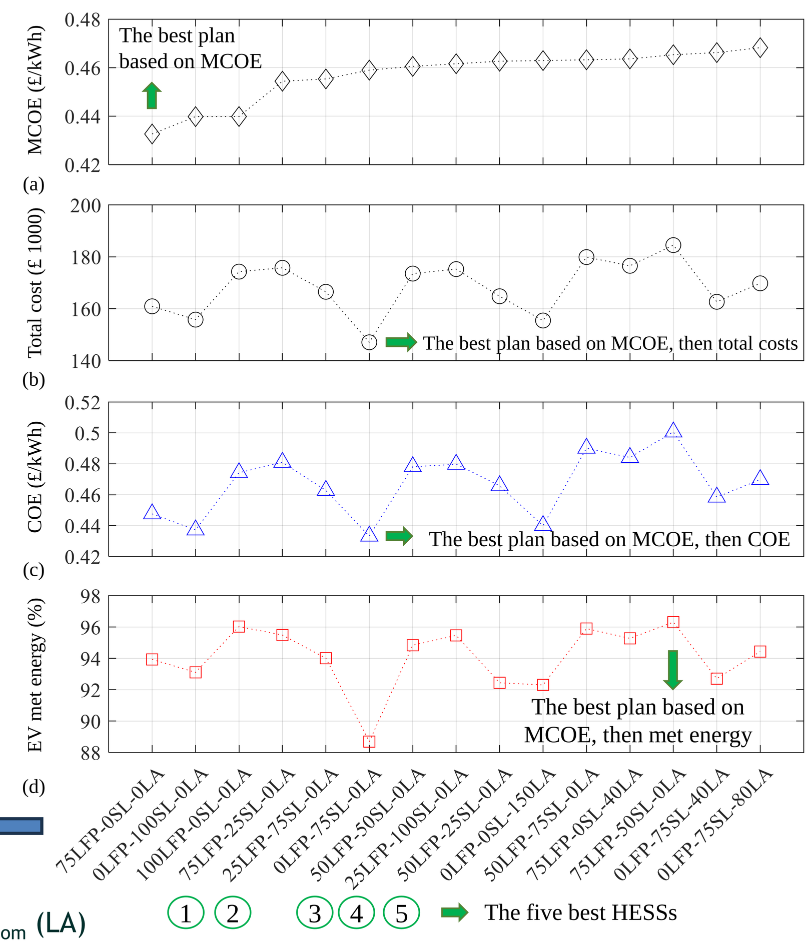
Feasible systems:

New Li-ion ESS nominal capacity (kWh)	Second-life Li-ion ESS nominal capacity (kWh)	Lead-acid ESS nominal capacity (kWh)
0	0	0
25	25	40
50	50	80
75	75	120
100	100	150

Comparing best plans based on modified COE (MCOE) using total costs, COE, and met load

$$COE(£/kWh) = \frac{MG\ total\ cost\ (£)}{Met\ load\ (kWh)}$$

$$MCOE\left(\frac{£}{kWh}\right) = \frac{MG\ total\ cost\ (£) - ESS\ present\ value(£) + UML\ cost\ (£)}{Met\ load\ (kWh)}$$

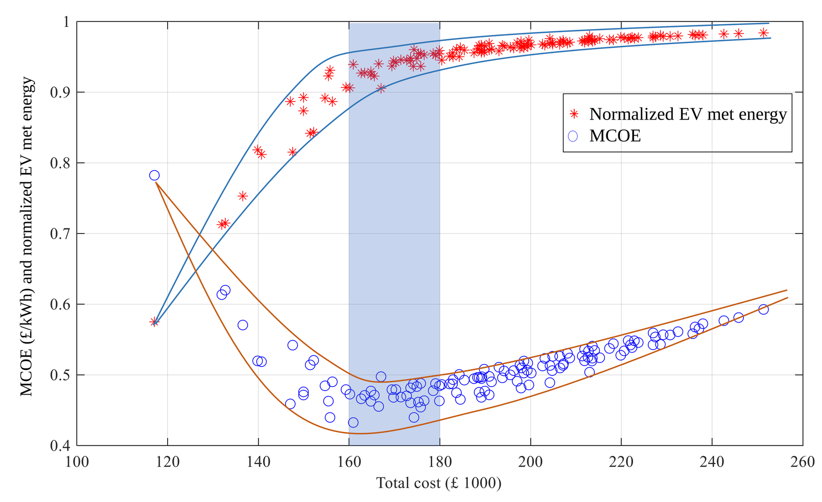


Capacity and technology of ESSs used in best plans:

New Li-ion kWh_{nom} (LFP) - SL Li-ion kWh_{nom} (SL) - New Lead-acid kWh_{nom} (LA)

Decision making constrained by total costs and using PCOE and met load

- Each circle shows the MCOE and each star shows the normalized EV met energy for each plan.
- A limited band of total costs can be obtained for plans with maximum MCOE.
- EV met energy has a degree of freedom in the limited band of plans to be maximized investing more or be minimized paying less.



Decision making constrained by total costs and using PCOE and met load

$£\ 160{,}000 < Total\ cost < £\ 180{,}000\ and\ MCOE \leq 0.46\ £/kWh$

Nominal capacity (kWh) of ESSs in the HESS for different plans			Total cost (£)	EV met energy (%)	MCOE (£/kWh)
New Li-ion ESS	Second-life Li-ion ESS	New Lead-acid ESS			
75	0	0	160,921	93.9	0.43
25	75	0	166,521	94.1	0.46
0	75	80	169,786	94.8	0.46
0	100	40	171,416	94.5	0.46
50	0	80	172,686	94.9	0.46
50	50	0	173,546	94.9	0.46
100	0	0	174,296	96	0.44
25	100	0	175,271	95.6	0.46
75	25	0	175,771	95.5	0.46
75	0	40	176,541	95.6	0.46
50	75	0	179,896	96.1	0.46

Conclusions

- Decision making based on techno-economic analysis can be done using different characteristics, e.g. COE, load met/unmet energy, total costs, or net present costs, where using each characteristic may lead to a specific plan as the best plan.
- The MCOE is a powerful techno-economic measure including the COE, the present value of ESSs after the studied period, and the virtual cost of EV unmet energy since it gathers several important technical and economic characteristics together.
- Most of the best approaches include only different capacities of single ESSs of new and second-life battery technologies.
- Multi-objective decision making is one of the best ways to select the best plan constrained by several characteristics. A multi-objective decision making is done here by constraining the total costs of plans while a band of minimum values of the MCOE is assumed. The limited plans based on the total costs and the MCOE also include a range of EV met energy percentage. Approaches with maximum EV met energy lead to more investment whereas approaches with minimum EV met energy result in low satisfaction of EV charging station users.

Next Steps

- Developing energy models of an electrolyzer, Fuel cell, and flow battery to extend HESS studies including these ESSs
- Developing electrical models of the components to simulate the action of the demonstrator system

Related papers to output results

[1] M. Naderi, Y. Al-Wreikat, D. Palmer, M. Smith, A. Khazali, E. Fraser, D. T. Gladwin, M. P. Foster, E. E. F. Ballantyne, A. Cruden, and D. A. Stone, "Techno-economic planning of a fully renewable energy-based autonomous microgrid studying single and hybrid energy storage systems", ready for submission.

[2] M. Naderi, D. Palmer, M. N. Munoz, Y. Al-Wreikat, M. Smith, E. Fraser, E. E. F. Ballantyne, D. T. Gladwin, M. P. Foster, D. A. Stone, "Modelling and sizing sensitivity analysis of a fully renewable energy-based electric vehicle charging station microgrid" submitted.

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