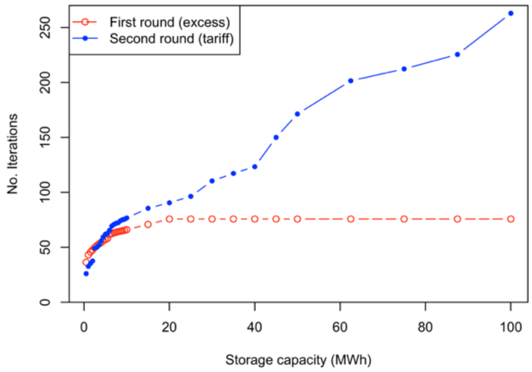

Fig.7. Average number of storage iteration loops per time slot selected against storage capacity for 2 rounds of ESS procedure.

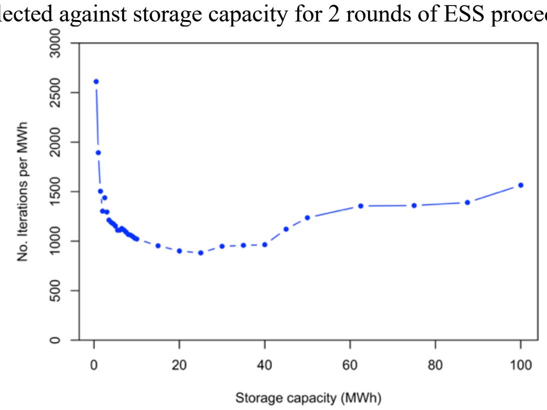

Fig.8. Number iterations needed per MWh of electricity delivered by the ESS, against storage capacity.

Translating the number of iterations into actual computing time, the CPU time needed by a relatively low-spec laptop (Macbook Air from 2015, 1.6. GHz Dual-core i5), even the largest ESS capacity used here on a data set of half-hourly data (17 568 slots) was completed in less than 20 s.

4. Conclusions

This paper has introduced a simulation tool to model the optimum operation of an energy storage system in a time series energy model using known or prescribed load and generation data. As such it implicitly assumes perfect knowledge which can be used to simulate the optimum or benchmark performance of an ESS. This model has been demonstrated in a case study to work reliably and produce results fully consistent with expectations.

As such, the model can be implemented for a broad range of energy systems models which are commonly used to understand the system dynamics as well as to provide a guide in the systems design process. It could be used in in conjunction with forecasts of generation and demand. In this case, it would show the optimum scheduling for the estimated prediction horizon. The only change to implement the model in predictive scheduling would be to initialise the ESS not at its minimum SoC but at the actual SoC at the beginning of the predicted period (line 5).

Currently, the ESS is represented by a small number of typical performance characteristics and is therefore flexibly to be applied across a large range of energy storage technologies. Given the transparent nature of the algorithm, it is easy to incorporate technological constraints, such as ramp rates. The most challenging, but not insurmountable, aspect appears so far to be complex self-discharge characteristics if they depend on current state factors as well as its history, as found with Li-Ion batteries [12,13], which show an initial rapid loss after charging followed by a more gradual self-discharge, as well as a degradation of capacity over time and use.

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