Economic analysis of electrolyzer / fuel cell-based energy storage systems via price arbitrage operation

CHALMERS UNIVERSITY OF TECHNOLOGY

Course: TRA275 Fuel cell systems

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INTRODUCTION

Context: As power systems around the world are comprised of a larger portion intermittent renewables variability in energy prices over a typical 24 hour period increases and the possibility of profitable price arbitrage grows in step with it. Fundamentally grid arbitrage relies on some method of moving power production from one point in time to another but which method will end upp being more profitable remains to be seen.

Aim of the study: This study aims to understand if it is possible to turn a profit by using a fuel cell and electrolyzer system and only buying electricity from or selling electricity to the power grid.

Method: using a provided piece of Matlab programming utilising the optimisation tool box and data provided by our project supervisor. In this study it is assumed that, the power of fuel cells is fixed at 100MW, the efficiency of the electrolyzer is 70%, the fuel cells is 50% and that of the converter is 98%. It is also impossible to exceed 95% of the storage capacity. From the results of fig. 1/2/3 , it is assumed that the CAPEX of storage is fixed at 20$/kg of hydrogen by using a cavern and is generally trivial in the end. Finally, all the prices are fixed all over the years.

Hypothesis: That the production of hydrogen through elerctrolysis and the consumption of hydrogen in a fuel cell already constitutes a viable method of price arbitrage in limited context but that the viability will increase in the future.

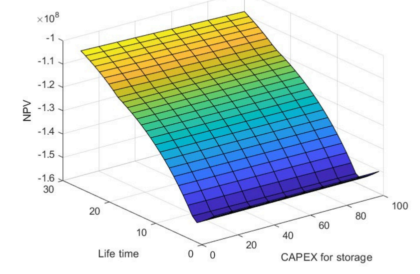

fig. 2: Net Present Value (NPV) in function of the CAPEX for the storage and the life time for a typical workday in June

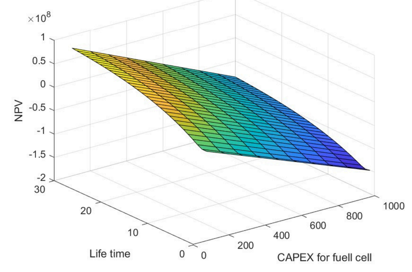

fig. 1: Net Present Value (NPV) in function of the CAPEX for fuell cells and the life time for a typical workday in June

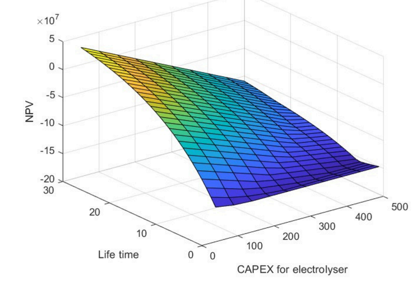

fig. 3: Net Present Value (NPV) in function of the CAPEX for the electrolyzer and the life time for a typical workday in June

MONTHLY STUDY

To have interesting results the only results presented are during the same month in Sweden and in China in summer (August) to be able to compare them.

SWEDEN

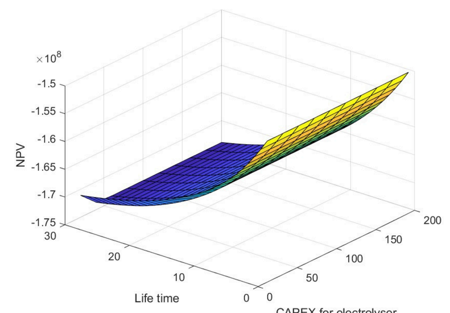

fig. 4: Net Present Value (NPV) in function of the CAPEX for the electrolyzer and the life time for a typical workday in August in Sweden

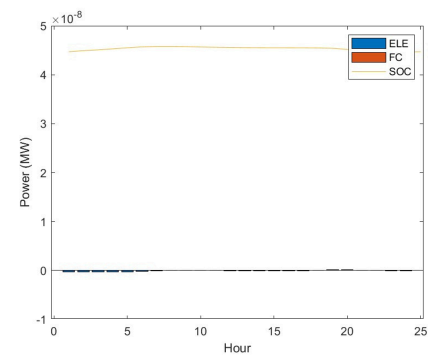

fig. 5: Power stored and used by the electrolyzer and the fuel cells for a typical workday in August in Sweden

In Sweden, the gap between the lowest and highest price in a day is not large enough to have a real opportunity to do arbitrage and to at least earn more than what is spent as OPEX on the electrolyzer necessary to do that arbitrage, so money is lost during the entire period that the system is installed giving an optimal solution of having almost no electrolyzer and essentially just letting the fuel cell sit. In fig. 5 and 4 we see the optimal hydrogen in storage (SOC) over a 24 our period and the relationship between the net present value and both the life time of the system and capex if the electrolyzer respectively (these are the same reletionship displayed in fig. 6 and 7).

CHINA

In China during the summer, the electricity price varies enough to consider using the method in question to make money. In fact, according to fig. 6, if the price for an electrolyzer is low enough (below 180$/kW) assuming a price for fuel cells at 800$/kW, it starts to be interesting to invest in that kind of system for at least 20 years. In figures 6 and 7 is illustrated, a system with an electrolyzer of 256 kW, and a storage capacity around 3175 kg for around 30 years the system can be viable with an economical point of view. It should be noted that a very similar system was viable in July giving two month where the system could generate a profit.

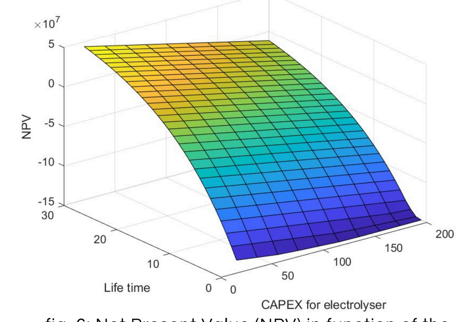

fig. 6: Net Present Value (NPV) in function of the CAPEX for the electrolyzer and the life time for a typical workday in August in China

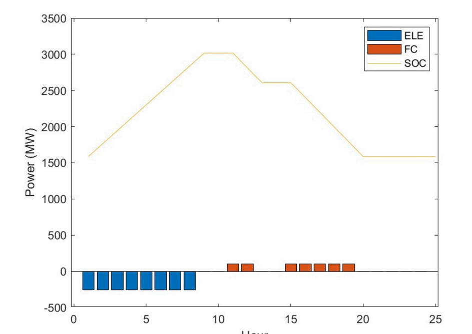

fig. 7: Power stored and used by the electrolyzer and the fuel cells for a typical workday in August in China

YEARLY STUDY

Another question that could be asked, is if it's possible to install any kind of arbitrage system in Sweden and to have it be viable aside from simple day to day? The answer could be to try and use the price variation over a year instead of only one month or day. to examine this the values for a typical day were taken each month and set end to end creating an artificial "day" that lasts 288 hours and using that too represent the variation over a year. This methodology may seem strange but it was the best compromise given that we did not have access to the processing power to solve the equation represented by a year in full. The main issue with this methodology is that potential profits from months where that is possible to do arbitrage day to day are missing, to resolve this calculations where done both with this uncompensated for and compensated for with a profit multiple of between 1.15 and 1.5.

Results: Using this methodology it does not seem profitable to try and exploit price differences over a year in either sweden or china atleast not with any reasonable cost for the fuel cell and electrolyzer.

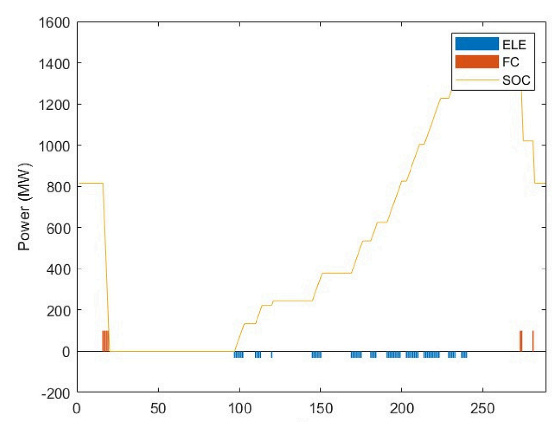

fig.8 : Power stored and used by the electrolyzer and the fuel cells in Sweden for a year with the CAPEX for fuel cells and electrolyzer at 200 $/kW.
result: NPV=-33152748 $

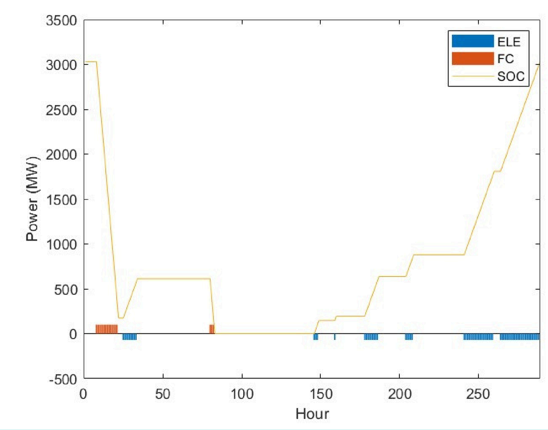

fig.9 : Power stored and used by the electrolyzer and the fuel cellsin China for a year with the CAPEX for fuel cells and electrolyzer at 200 $/kW.
result: NPV=-25512723$

DISCUSSION

As we can see the original hypothesis was not entirely incorrect but the scope of the context in which this method of price arbitrage was viable was unexpectedly small and reliant on assumption of prices which although not far from current prices still constitute a deviation from the most likely case. The most obvious angle to explain this unprofitability is the cost of elecrolyzers and fuels cells given that that is how we simuleted profitability in this study but there is also some benefit to discussing the fact that arbitrage of this manner in an electricity market seems to be untenable for a myriad of reasons. primally the fact that unstable and highly variable prices are undesirable from a consumer perspective meaning that governments and market forces both work toward decreasing the difference in price over time. A key reason why the energy prices in Sweden are not variable enough for this to turn a profit is that there is a large portion of the grid composed of hydro power which can handle peak consumption. Interestingly enough the way margin cost energy markets utilise reservoir based hydro power could reveal a future for hydrogen storage, specifically the way hydro is allowed to base its margin cost on the opportunity cost of future production. This would also help avoid the most extreme cannibalisation which could occur in a market where arbitrage is common which makes investments more attractive as the effect of increased penetration on price is more gradual.

CONCLUSION

In conclusion, all our tests gave similar results. Unfortunately, because of the high CAPEX of electrolyzers and fuel cells, it is necessary to have very specific conditions for an implementation of a system that uses electrolyzer and fuel cells to buy and sell electricity to the power grid to turn a profit if only price arbitrage is considered. In some very specific cases in China, it is possible to make profit, but only in cases that have a very low CAPEX for the electrolyzer and that is not realistic now. Because of that, in the future it will likely be the case that, if electricity price variability increases enough and the relevant technologies are produced at a larger scale decreasing their price, that kind of systems will profitable to implement, but still likely only in very specific places, as China.

TO GO FURTHER

Due to constraints on time the study can be further developed by different ideas such as buying electricity in one country and selling it in another with some transportation constraints or by supplementing arbitrage with selling hydrogen to industrial processes.