Economic Analysis of Li-Ion Battery Energy Storage System

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Abstract

Battery energy storage systems (BESS) serve as vital elements in deploying renewable energy sources into electrical grids in addition to enhancing the transient dynamics of those power grids. This research details an application program that analyzes a grid connected BESS in common situations an operator may encounter and outputs the optimal action to be conducted.

Theoretical Background

- A conventional analysis would take into account the static expenses associated with BESS such as installation and dynamic expenses regarding maintenance and operate.
- These expenses would then be collated with continued forecasted profitability of the BESS in common conditions that occur at the location of operation.

Current Research:

- Through this study and analysis, power system operators can gain a thorough understanding of the financial benefits of BESS that come along with operating the systems optimally.
- Furthermore, this analysis aids in ensuring a painless integration of BESS into power grids.

Method

In Long Short Term Memory (LSTM), this set of algorithm for the Artificial Intelligence (AI) overcomes the vanishing gradient issue. The LSTM is able to:

- utilize long-term dependencies compared to other models.
- continue to remember its dependencies from many time steps back.
- preserve error that can be back propagated through its time and layers, allowing it to maintain a more constant error and allow the model to learn up to as many steps as over 1000, which is incredibly important for understanding the flow in finding the next price in LMP, which makes LSTM the algorithm worth going for in this case [1].
- be designed from ground up to remember its dependencies, and on top of that, it appears as a cell-like structure shown in Fig. 1.
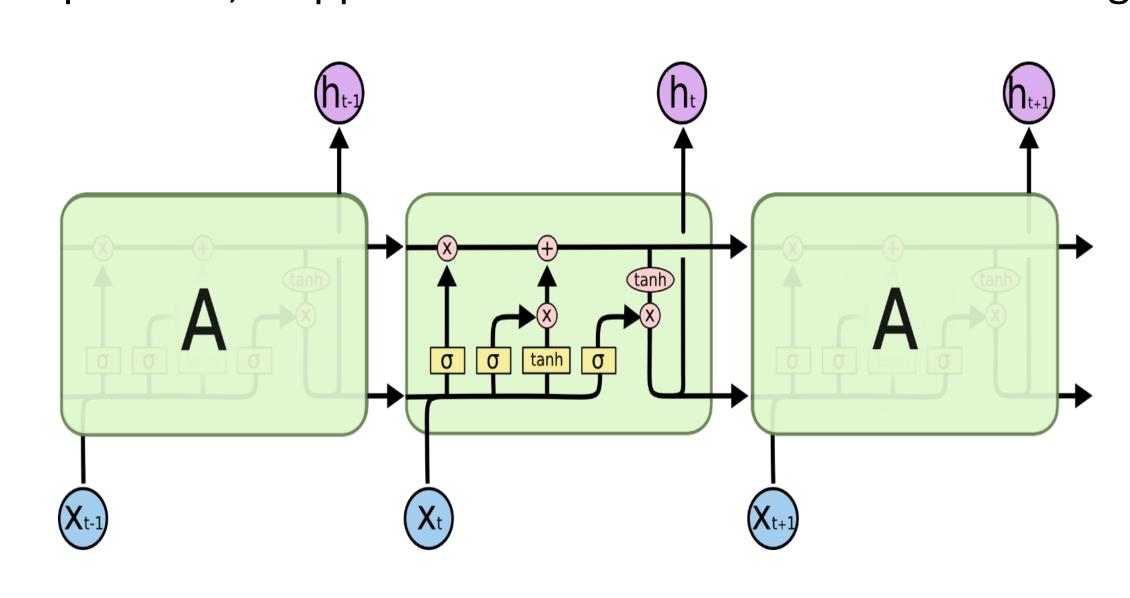
Fig. 1 LSTM Structure

Results

Once the AI was trained with various sets of LMP data and its respective components, the AI was able to adequately predict near-future LMP values. As shown in Fig. 2, there are very few discrepancies when comparing the AI's prediction and actual data.
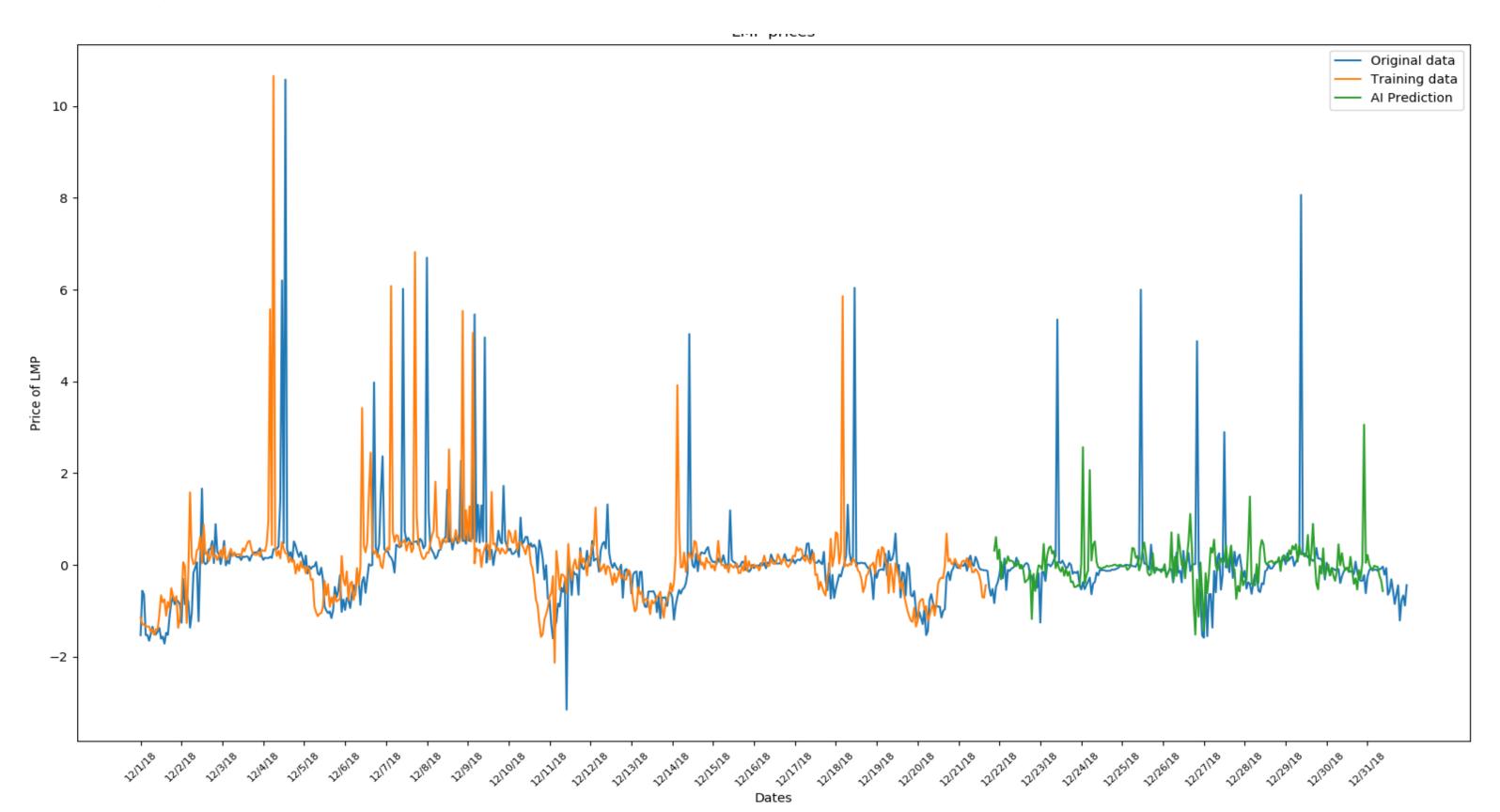
Fig.2 AI training and predicting

After training the AI to be fairly accurate, the predictive algorithm was integrated with the original economical analysis algorithm. By being able to accurately predict the near future costs of energy, the algorithm was enhanced tremendously having to consider all the other potential scenarios that come along with a known future LMP [2]. As shown in Fig. 3, the algorithm's philosophy takes into account not only present and past LMPs, but also the predictive LMP output by the AI.
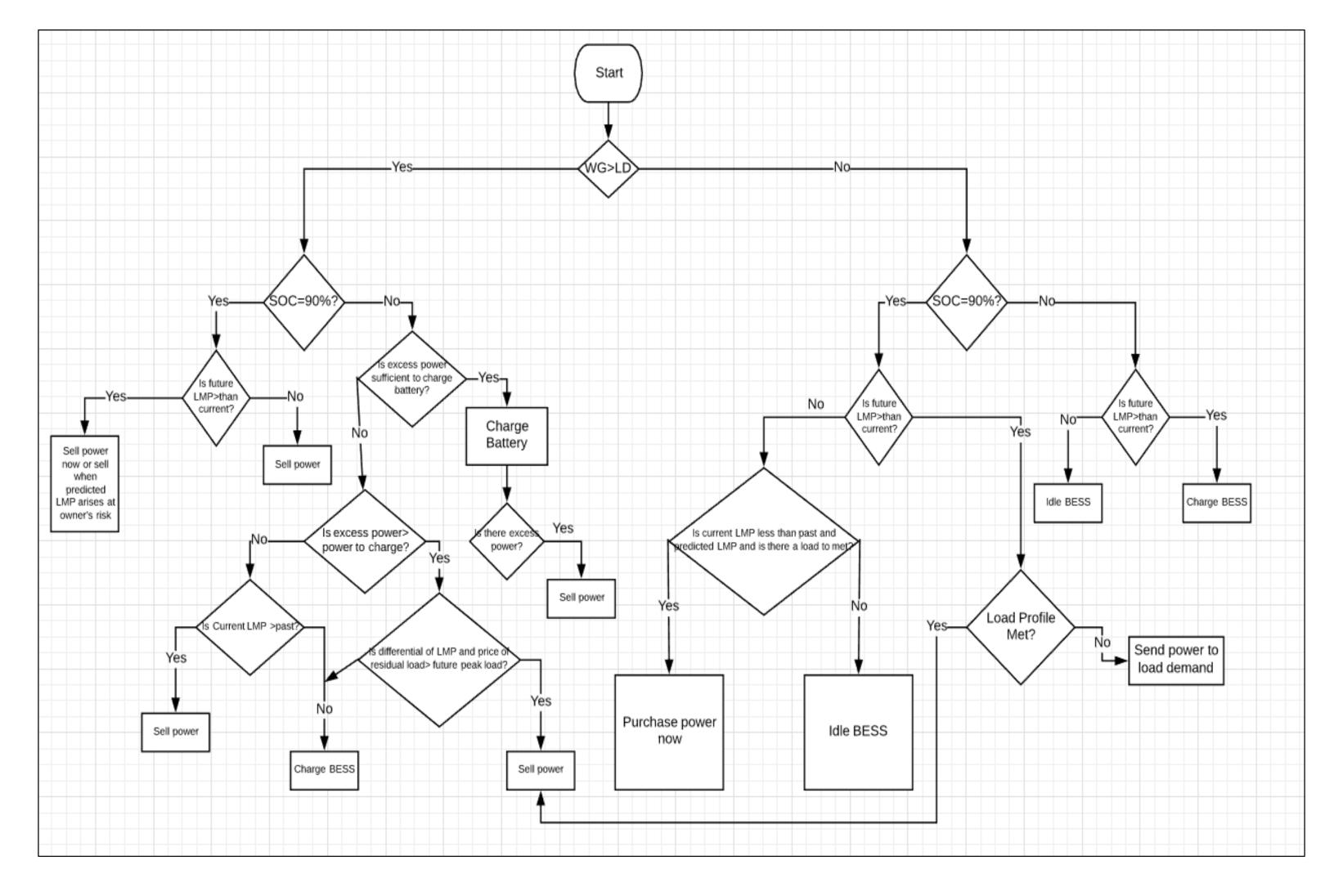
Fig.3 Algorithm Philosophy

Discussion

With both the predictive AI and economic analysis algorithm being refined and integrated, a user interface as shown Fig.4 was then built in which operators can input their own data and/or populate it from excel files. Once the data is fed to the program, the AI is trained and provides a predicted future LMP price. This predicted price is then incorporated into the economic analysis algorithm which is followed by an appropriate output to charge, discharge, or allow the BESS to remain idle depending on the situation.
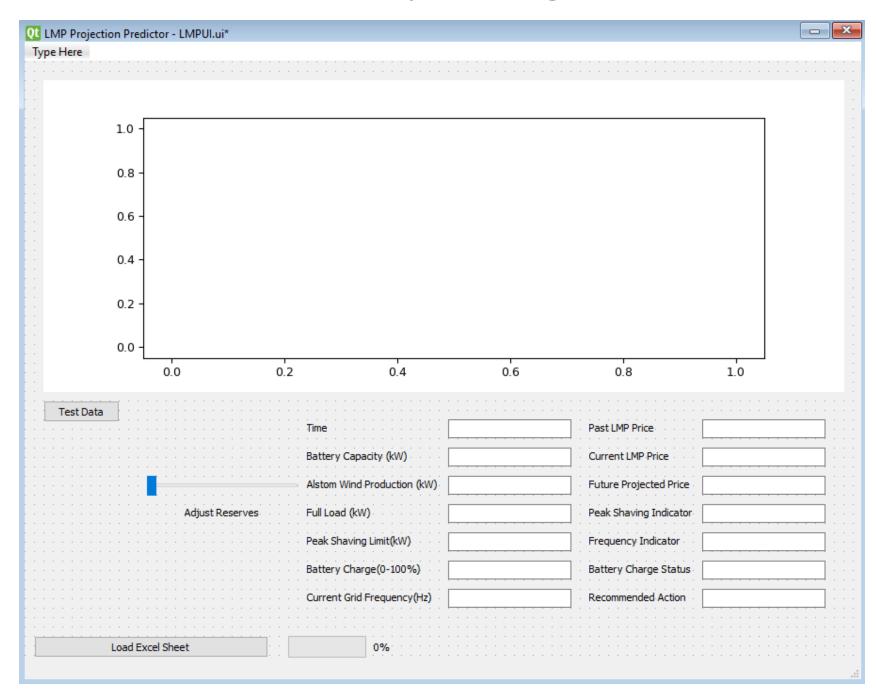
Fig. 4 User Interface

Both the predictive AI and BESS predictive algorithm could be researched further to include more of the elements thereby enhancing the algorithm philosophy. This project leads to additional research to accommodate multiple energy sources and/or BESSs.

References

[1] Y. Bengio, P. Simard and P. Frasconi, "Learning long-term dependencies with gradient descent is difficult," in IEEE Transactions on Neural Networks, vol. 5, no. 2, pp. 157-166, March 1994.

[2] G. Hamoud and I. Bradley, "Assessment of transmission congestion cost and locational marginal pricing in a competitive electricity market," in *IEEE Transactions on Power Systems*, vol. 19, no. 2, pp. 769-775, May 2004.

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