An Emulation Framework for Electric Vehicle Charging Using IEC-61499 Function Blocks

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I. Background

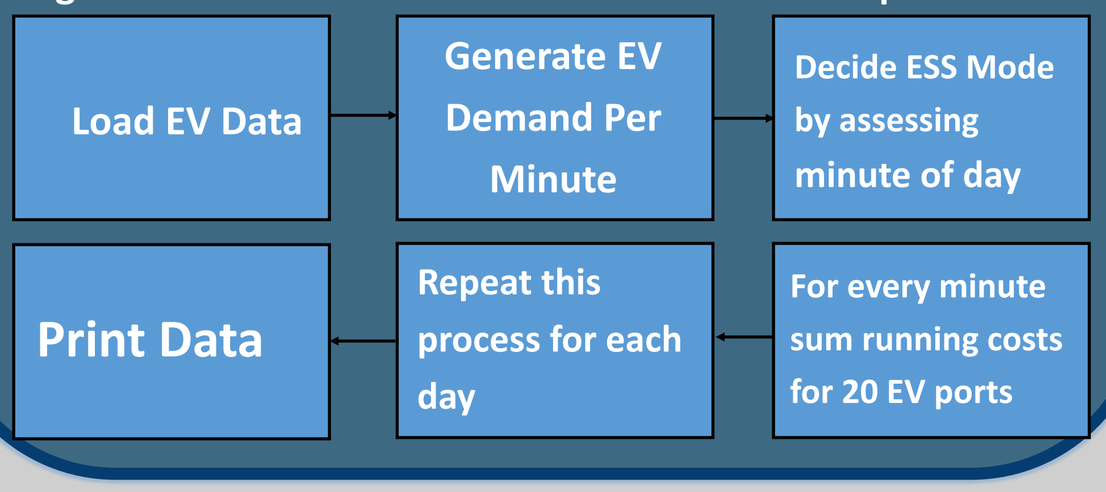
Electric vehicles (EV) are extremely relevant in the current climate. Countries around the world are pushing towards using them more widely. This is due to both environmental and cost-saving factors. Singapore is a good example of a country adopting the wide-spread use of electric vehicles. There is a need for efficient electric vehicle charging. The optimising of electric vehicle charging stations through the use of an energy storage system (ESS) can help achieve this.

Intent

To investigate whether a Singaporean case-study of an electric-vehicle charging station with ESS can be improved upon.

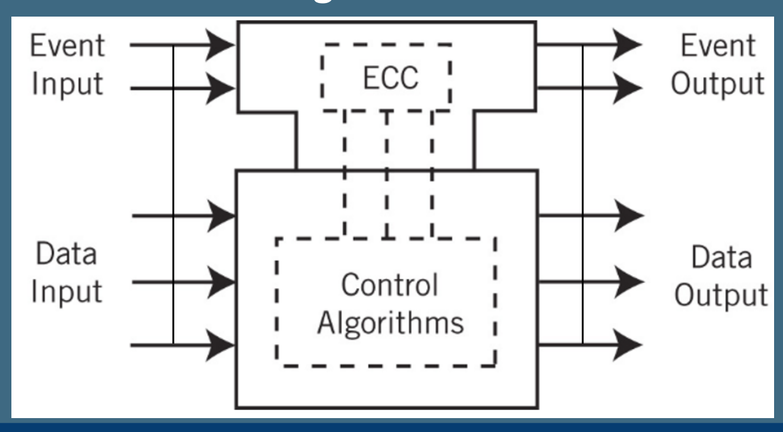
II. MATLAB Algorithm

- A MATLAB Algorithm set the foundation for the project.
- Based on Singapore, this case-study looked at an Electric Vehicle Charging Station with an energy storage system which has 20 charging ports (5 fast and 15 normal).
- ESS can operate in three states: Peak, Off-Peak and Off-Peak Charging. State decision is based on minute of the day.
- Algorithm does not run in real-time as states are predefined.



III. IEC-61499 Function Blocks

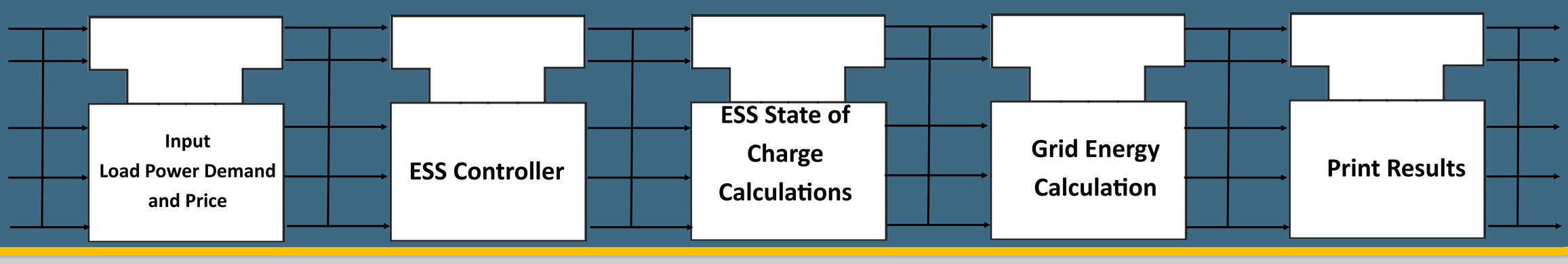
- This standard allows programming to be done in an object-orientated manner.
- Basic Function Blocks are the building unit of this standard.
- Each block has an execution control chart to take in and responds to input events to then give outputs.
- This is done via control algorithms.



IV. Algorithm Implementation in IEC-61499

- Implementing the MATLAB Algorithm with function blocks allows testing of the emulation environment three different ways
- This is done by simply swapping the 'controller' block with the new form of testing method to see which gives minimum running cost
- This is possible due to the benefits of IEC-61499 (others including portability, reusability, interoperability).

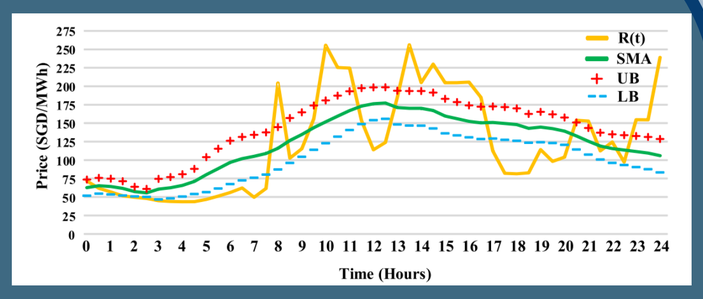
V. Overview of Function Block Environment



VI. Forms of Testing

1.Bollinger Bands

- A simple moving average where an upper/ lower threshold is calculated.
- Above upper band is 'Peak', between Upper and Lower band is 'Off-Peak' and below lower band is 'Off-Peak Charging'.



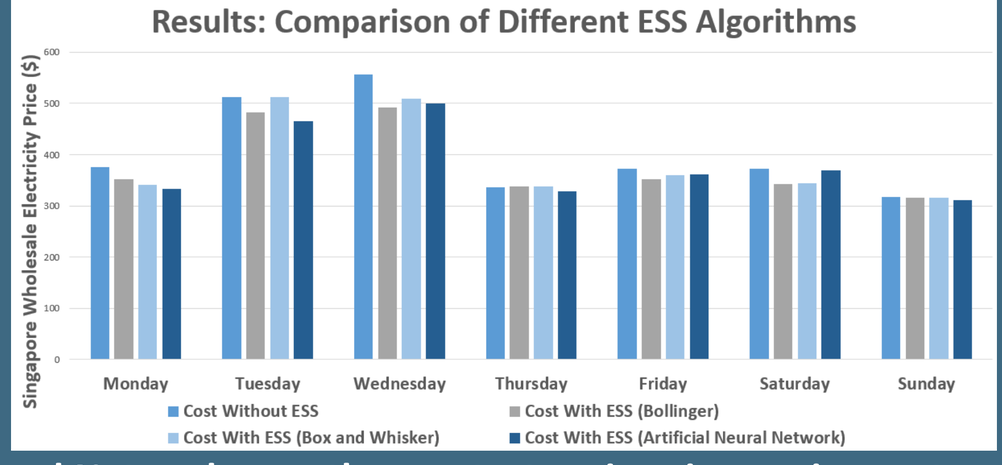
2.Box and Whisker

- Medium, Upper Quartile and Lower Quartile were calculated from electricity price. These values set the thresholds for deciding which state the energy storage system should operate in.
- Power demand from electric vehicle users was also used in deciding the energy storage system state.

3.Artificial Neural Network

- Neural network takes the current electricity price and power demand as well as the forecasted price and previous demand.
- It then predicts the likely state of the energy storage system.

VII. Results



- Neural Network gave the greatest savings in running costs (closely followed by Bollinger bands and then Box and Whisker) .
- Days with low overall cost see the least improvement from ESS implementation.

VIII. Conclusions

- The results indicate the neural network is the best for minimising costs. The intent of the research project was met.
- Looking ahead, the combination of neural networks with IEC-61499 looks very promising and further research should be done.

Bollinger Bands Example: https://www.researchgate.net/figure/Wholesale-Electricity-price-for-a-typical-day-and-price-band-allocation_fig2_308804006
Basic Function Block Figure: https://www.controldesign.com/articles/2007/202/

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