EEE #140

Energy Storage Requirements for the SA Grid

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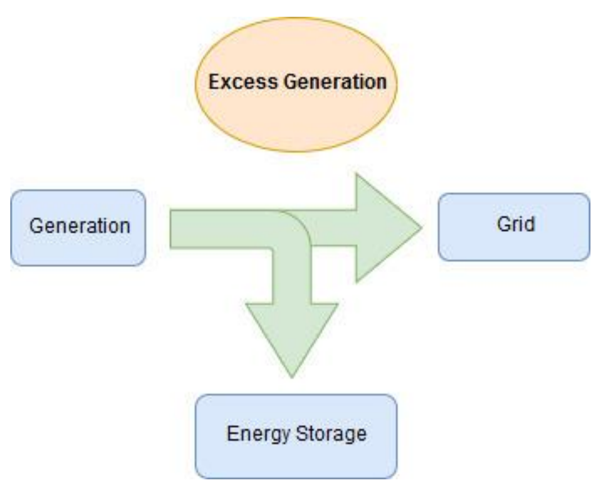
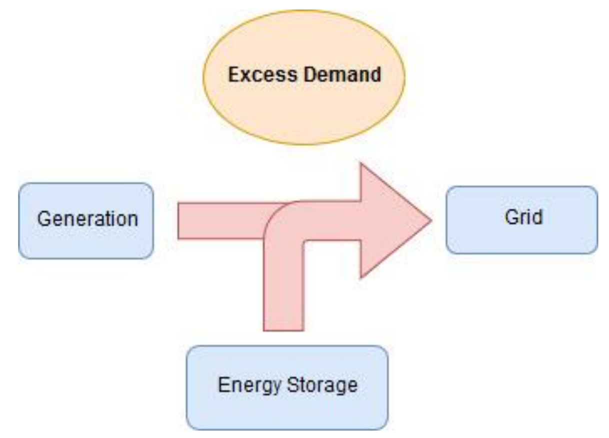
Background & Motivation

Renewable energy generation is becoming more and more prevalent in South Australia. Although they have many benefits compared to fossil fuel generators, such as low carbon emissions and unlimited supply, there are some drawbacks. The major drawback is their intermittency; they are not able to generate energy consistently around the clock.



These limitations have been obvious in South Australia in recent times, with load shedding and blackouts caused by insufficient generation to meet demand at peak times. Energy storage systems can provide a solution to this by allowing energy to be stored from the output of renewable generators when it is not needed, and then called upon from the storage system when it is.



Project Aims

This project has aimed to determine how an energy storage solution can best be implemented in South Australia to improve the reliability and continuity of our energy supply. This was to be accomplished through:

- The creation of a robust database to be used in the simulation of a battery storage solution
- The exploration of how to utilise an energy storage system by managing how it is charged and discharged.

The Data

At the beginning of the project we had no data to work off so we developed a database using the data that is freely available from the AEMO data dashboard.
We incorporated data for the following datasets:

- Generator Outputs (MW) for all dispatchable generators in the NEM.
- Data for each of the 5 regions in the NEM:
  - Demand
  - Spot Price
  - Modelled rooftop photovoltaic generation
  - Available and Dispatchable generation
- Interconnector power flows (MW) for every region interconnector.

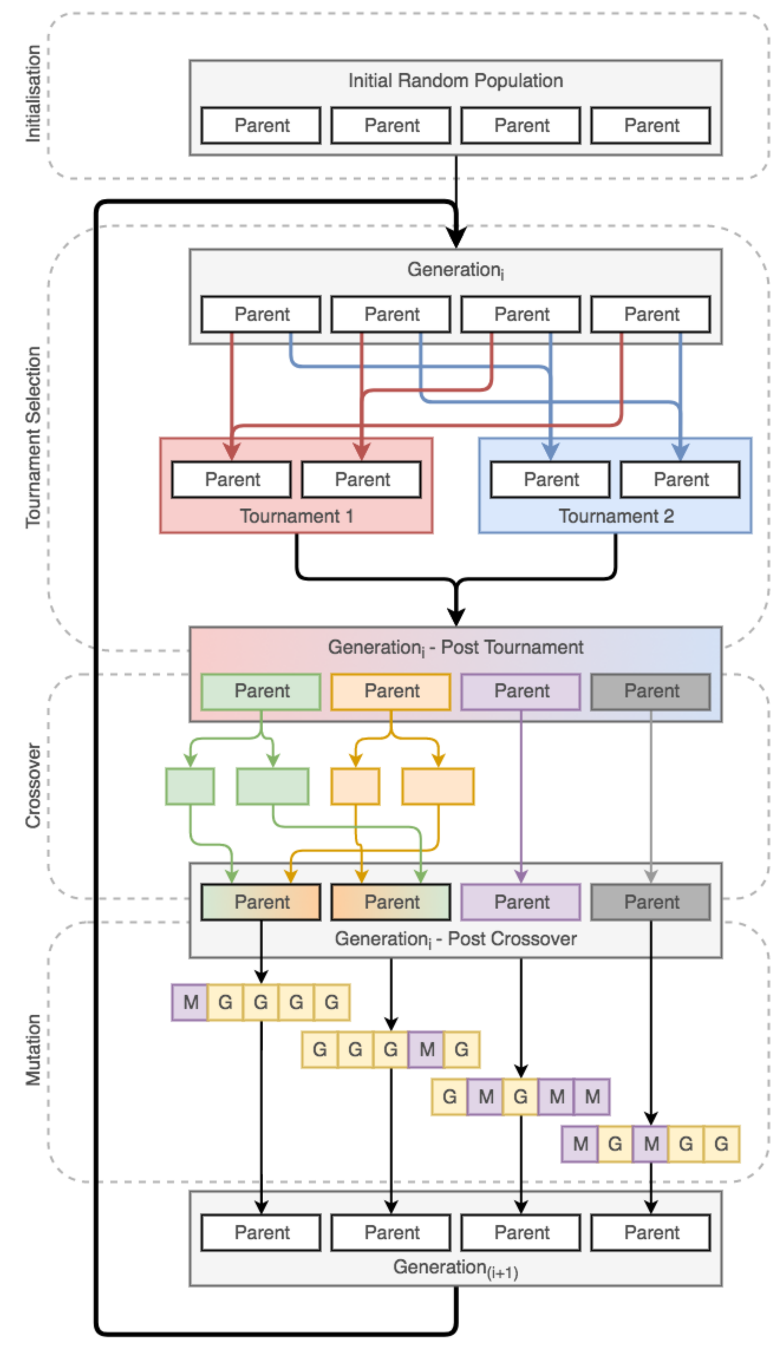
The data available was not complete, many generators were missing the descriptors that would allow them to be categorised into different regions or generator types (such as fossil fuel based or renewables based).

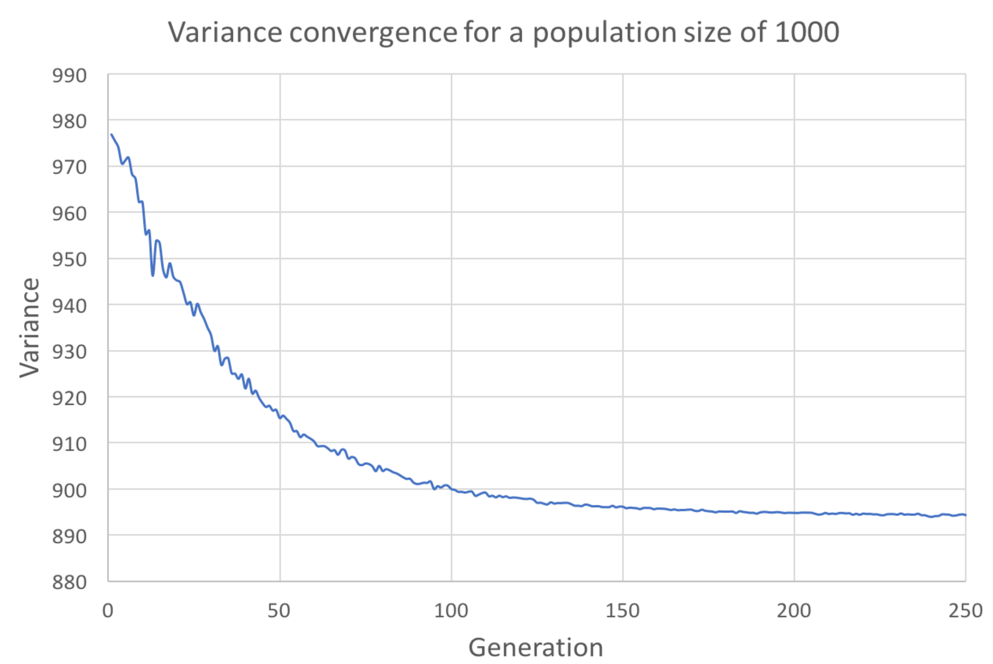
Genetic Algorithms

Genetic algorithms (GA) mimic the biological process of evolution to search the solution space of a problem for near globally optimal solutions. The major steps in a GA are:

1. Create a list of genes to form a parent (a parent is one solution to the problem)
2. Determine the fitness (quality of the solution) of the parent.
3. Perform a tournament selection (think tennis competition) and discard parents with poor fitness.
4. Mate the parents, crossing over the gene sets of each parent.
5. Mutate by changing genes at random.
6. Iterate steps 2-5 for at least 100,000 parents or until the GA converges to a suitable solution.

We developed a GA to solve energy storage problems as even a simple system has an enormous (infinite) range of possible solutions.



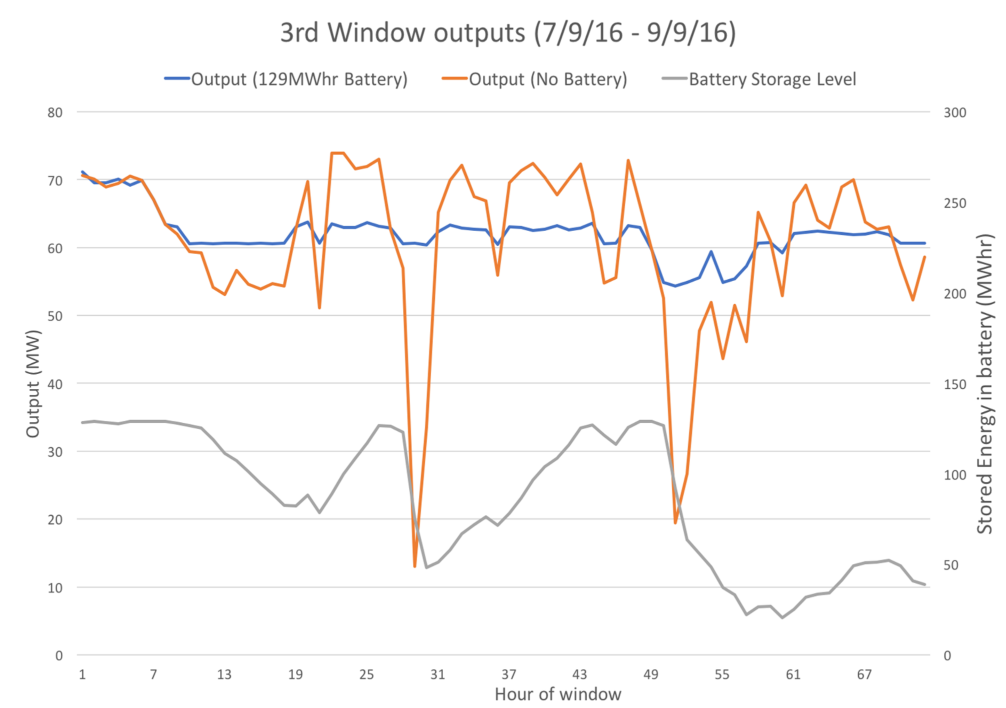


Solution Convergence

Our GA sought to minimise the variance of a generator's output using energy storage. The chart on the left is the result from the test run of our GA. The variance reaches a stable minimum after about 150 generations of 1000 parents. This corresponds to 150,000 possible solutions before optimal solutions are found. This test ran for 250 generations.

Variance Minimisation

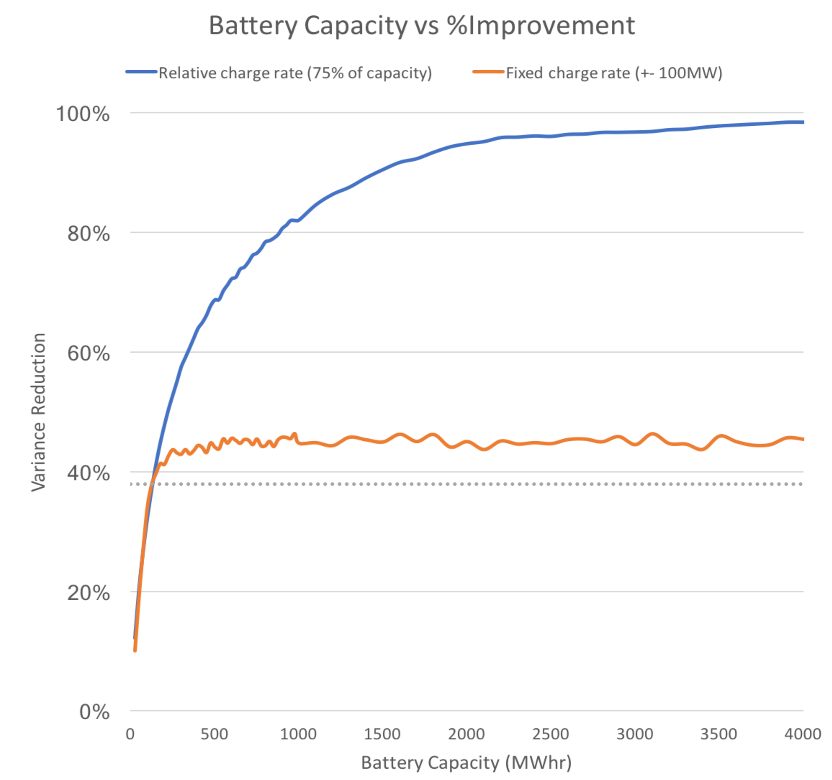
The chart on the right shows how energy storage can alter the output of a generator. The orange (no battery) line is highly variable with two steep drops in generation. The blue line uses the same data with a GA simulated battery, achieving near constant output. The grey line shows how the battery level rises and falls.



Storage Capacity

The chart on the right shows how much generator output variance can be reduced with different capacity batteries for:

- Fixed rated output (Orange line, ±100MW)
- Relative rated output (Blue line, 75% of capacity)
- 129MWhr capacity, 100MW output (dotted line)



Case Study

To explore the effect of a battery on smoothing wind generator output, the Tesla Inc. battery being installed at the Hornsdale wind farm was modelled and used to attempt to minimise the variance of the generation output of the wind farm.

Using a GA to manage the charging and discharging of this battery with a 129MWhr capacity and 100MW output yielded an improvement of 38.31% in the variance compared to the raw generation data. This is also a 10.55% improvement over managing the battery using a basic, constraint-based algorithm. Therefore, utilising a battery energy storage system that will soon be a part of the SA energy network can provide a notable benefit if used in this way.

Conversely, the size of the battery necessary to minimise the variance of the generation output of Hornsdale wind farm to a given value was also explored. As seen in the chart above, in order to reduce the variance of the generation data by 90%, a storage system with a capacity of 1500MWhr is required.

Conclusions

Through this project, it was found that managing an energy storage system intelligently using a GA can provide notable improvements in the variance of generator output. It can also improve the efficiency of a battery storage system compared to a naive management algorithm.

GA optimisation has shown to be promising based on the work done in this project. Through the use of GAs, and the data available in our database, future projects can look to devise an energy storage solution that enables renewable generation output to follow the energy demand requirements of SA in a way that is efficient and effective.