Comparison between Electricity Storage and Existing Alberta Site Dispatch Profiles

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Introduction

The purpose of this report is to assess whether estimated Alberta Interconnected Electric System (AIES)-connected energy (electricity) storage behavior is similar to the behavior of existing load and behind-the-fence (BTF) sites. For the purposes of this study, it is assumed that storage behavior is based on energy market price arbitrage as opposed to providing reserves, grid support, or other non-price related behavior.

Background

There have been several AIES-connected energy storage facilities proposed in Alberta and because there are no existing storage facilities, there is currently no actual data on how these sites behave with regard to taking load from the grid and putting supply onto the grid. In 2015, the University of Calgary (U of C) undertook a study which estimated storage dispatch profiles for different storage technologies and sizes, based on historic power pool prices. Based on this study, the AESO has undertaken a comparison of BTF, price responsive load (PRL), and other load profiles with different storage facilities. The following analysis investigates if there are any similarities between a storage facility and existing sites in Alberta.

Methodology

To investigate the relationship between storage dispatch and existing sites in Alberta, the generation and load profiles of storage facilities are compared to various existing sites using three methodologies. A visual comparison of hourly and daily average estimated storage profiles is compared to actual BTF site behavior, the distribution of net-to-grid load and generation dispatches between storage and BTF is compared, and correlation coefficients are estimated across the U of C's estimated storage shapes and various BTF and load sites. For confidentiality purposes, all names of sites and specific volumes are withheld to ensure any commercially sensitive data is protected.

Storage versus BTF Sites

For the purposes of this study, storage is compared to BTF sites because both can be net load to the grid, and at other times become net generation. The hypothesis is that in times of high prices, storage would inject power to the grid, and charge when prices are low. Price-responsive BTF sites should be similar, optimizing output as a function of price. Figures 1 and 2 below chart a hypothetical hourly battery dispatch from the U of C study, with a representative BTF site in Alberta. Negative values indicate net from the grid, or load.

Figure 1 shows that for this time period, the BTF site and storage technology tend to inject power on the grid during high prices, and typically withdraw or reduce production during low prices, indicating similar profiles.

Figure 1: BTF Site and Storage Dispatch

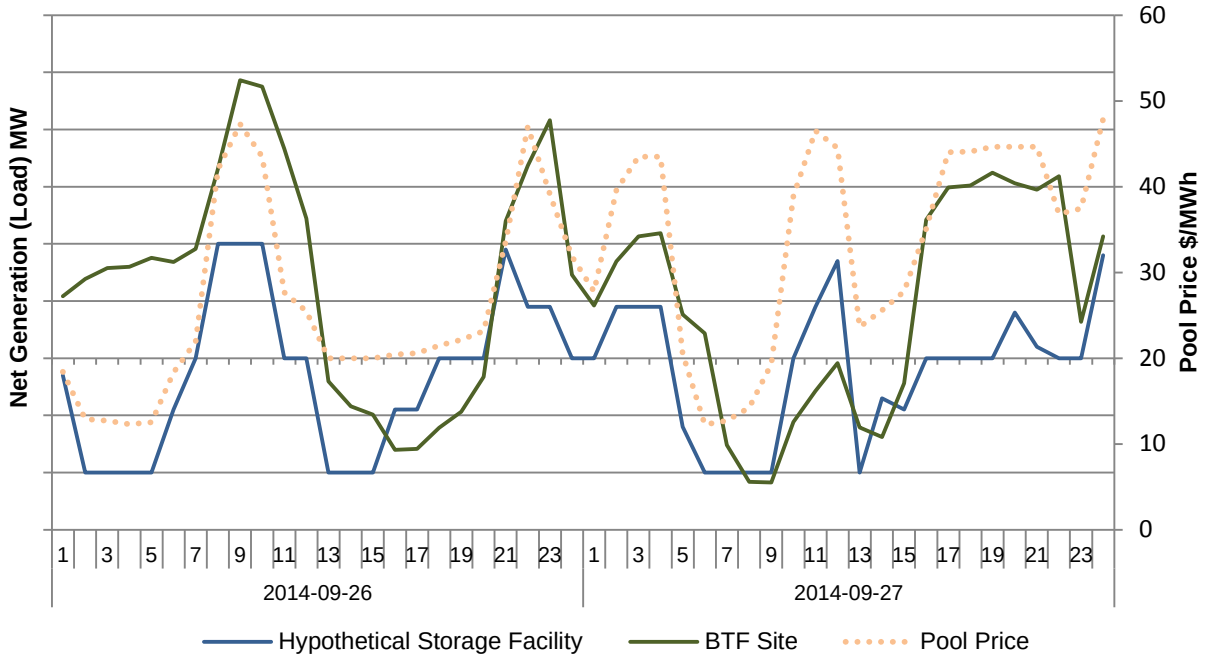


Figure 2 compares the same site and storage technology, but over a different period of time.

Figure 2: BTF Site and Storage Dispatch

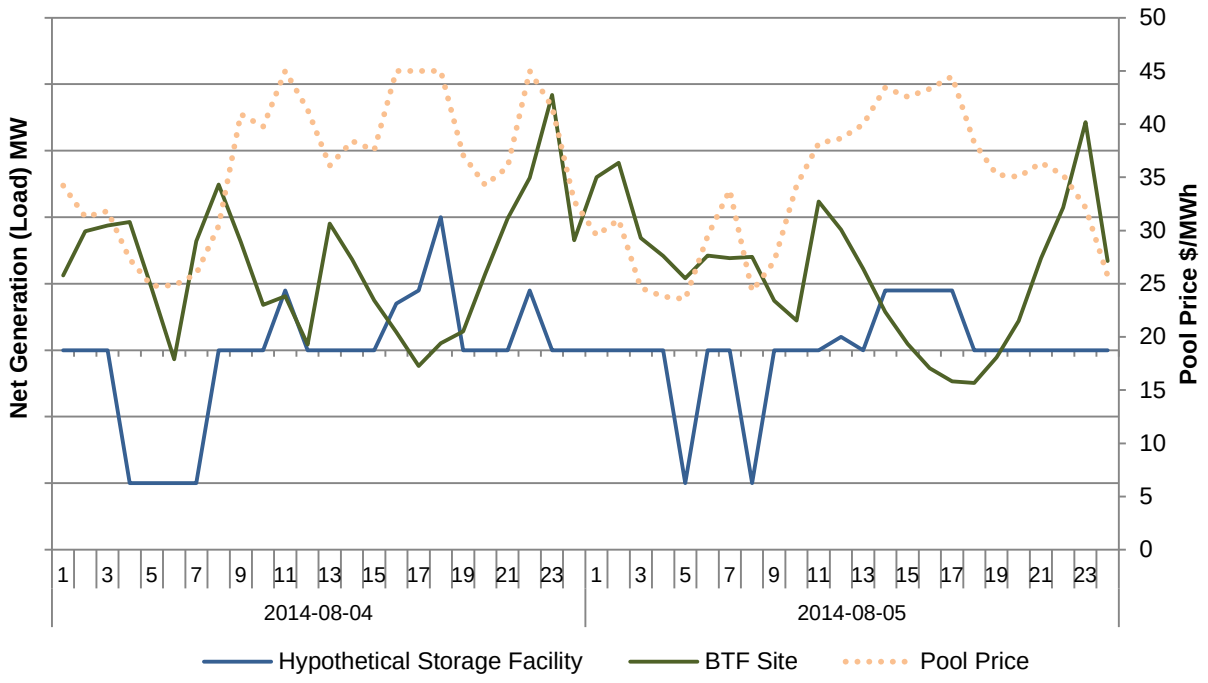


Figure 2 illustrates that the relationship of increasing generation (or decreasing load) during high priced hours and decreasing generation (or becoming net load) during low prices changes for the BTF site

compared to the storage facility. During the peak price on 2014-08-05, the BTF site becomes net load during peak prices while the storage facility optimally dispatches after charging that morning during low prices. This suggests that although BTF sites may be sophisticated enough to optimize output to maximize profits, they may still have operational requirements that cause them to alter their behavior.

BTF sites can operate as load or generation for prolonged periods whereas storage facilities have constraints on how long they can remain load or generation. An example of this can be seen in Figure 3 which shows a two-month range of daily average net generation of a different storage technology with a different BTF site.

Figure 3: Daily Average Dispatch BTF and Storage

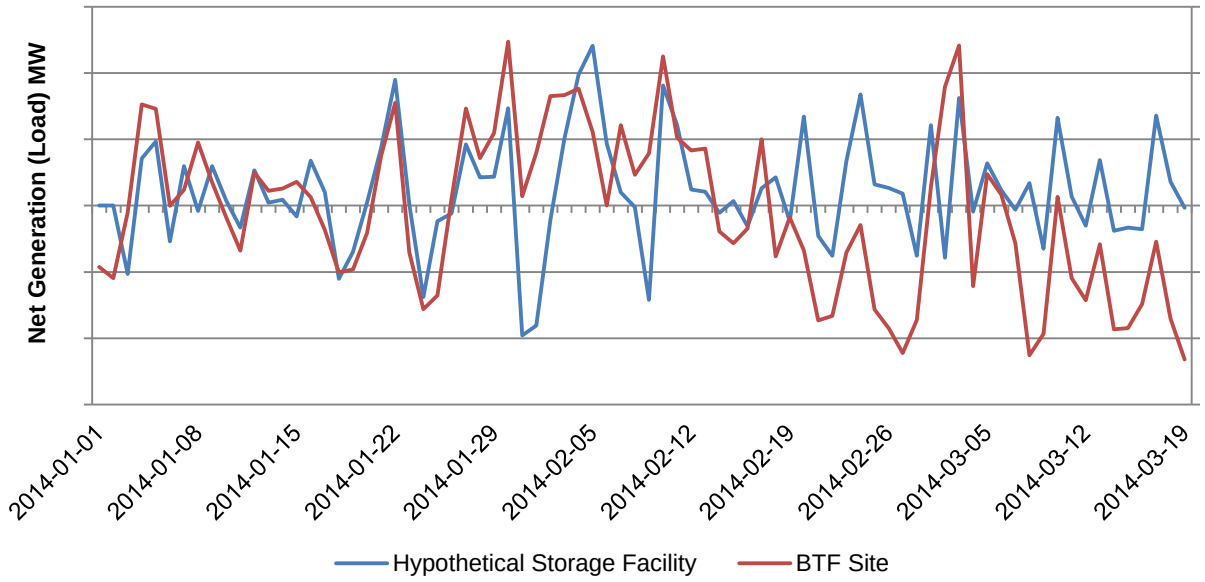


Figure 3 shows that over a longer period of time, this storage technology and BTF site tend to have days in which they net charge (or reduced generation in the case of the BTF site) and net discharge or increased generation. Since the BTF site does not have the same constraints as storage on the amount of time it can stay as net generation or load, the two profiles diverge in the second month. The BTF profile shows a downward trend while the storage facility hovers around zero.

Dispatch Distributions

Another useful metric to compare potential storage technologies and existing sites in Alberta is to look at their dispatch distributions. The histograms in Figures 4 and 5 show the frequency that a site has net generation or load within a certain range.

Figure 4: Dispatch Distribution of a Hypothetical Storage Facility

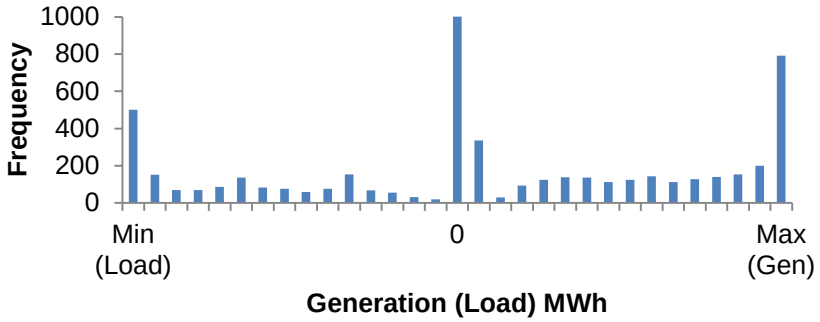
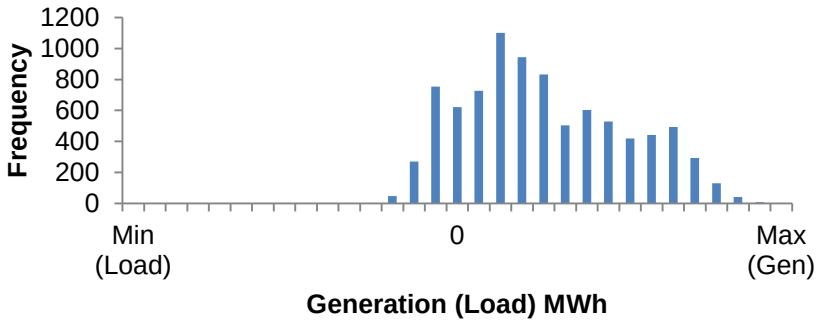
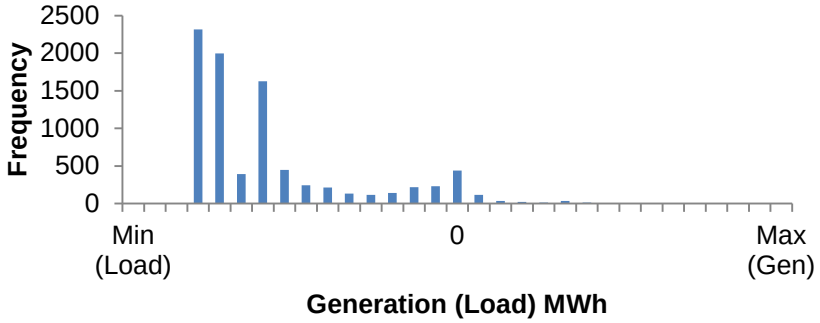


Figure 5: Dispatch Distribution of Select BTF Sites





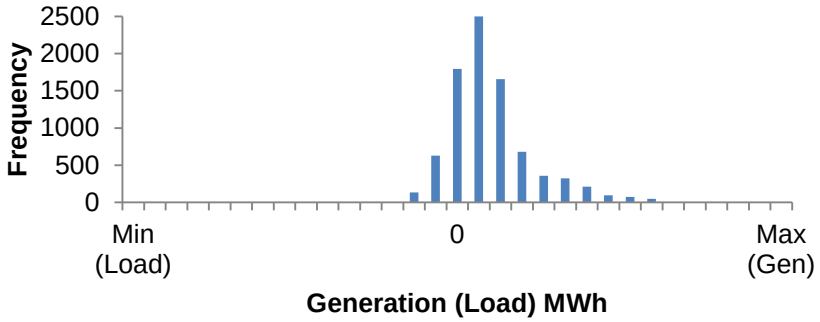


Figure 4 shows that storage facilities usually operate at their injection and withdrawal capacity or are neutral to the grid. This pattern is not typical at other sites which tend to deviate from around their mean values. Non-storage sites also rarely operate at the limits of their generation or load capacities.

Correlations

Correlations of storage dispatch profiles to various BTF and load sites are also examined. The correlation coefficient is a measure of the strength and direction of the linear relationship between two variables. A correlation coefficient of zero (0) indicates that there is no linear relationship between two variables while a correlation of positive one (+1) indicates perfect positive correlation (i.e. both sites move perfectly together). A correlation of negative one (-1) indicates a perfect negative correlation (i.e. the sites move completely inverse to each other).

The correlations are calculated from hourly data from 2014 using estimated hourly storage profiles with actual site behavior. The results are shown in Table 1 on the page below. Each cell represents the correlation between the net-to-grid flows of storage technology in the heading, and a particular load or BTF site. The U of C simulated each technology's optimal dispatch profile under demand transmission service (DTS) rates, and without. Correlations with both DTS and non-DTS profiles are estimated.

The correlation coefficient analysis suggests that there is a weak to moderate positive correlation between most storage profiles and most BTF sites, with a maximum correlation coefficient of 0.55. There is a weak positive correlation between most price sensitive load and most storage profiles. Between storage and residential load, the results show that they are moderately negatively correlated with the exception of one storage profile. Finally, farm load appears to be slightly negatively correlated with most storage profiles.

Conclusion

BTF site behavior demonstrates some similarities with estimated storage behavior. Both demonstrate optimized output as a function of price, there is similarity between their net-to-grid load and generation, and there are positive correlations between their behaviors. However, BTF sites can act as net-to-grid load or generation for prolonged periods of time, which storage cannot do, and storage sites tend to operate at either their input or output capacity limits or they idle.

Storage facilities do not show much similarity to PRL, urban or farm load. In the case of PRL, the correlation to storage is weakly positive at most while urban and farm loads demonstrate weak negative correlation indicating they tend to move in the opposite direction as storage.

Table 1: Correlation between Storage and Select Sites

Type	Site	8MW Lithium Ion No DTS	8MW Lithium Ion w/DTS	8MW NaS No DTS	8MW NaS w/DTS	8MW VRB No DTS	8MW VRB w/DTS	20MW Lithium Ion No DTS	20MW Lithium Ion w/DTS	20MW NaS No DTS	20MW NaS w/DTS	20MW VRB No DTS	20MW VRB w/DTS	150MW PHS No DTS	150MW PHS w/DTS	150MW CAES No DTS	150MW CAES w/DTS
BTF	A	0.30	0.29	0.27	0.26	0.31	0.31	0.29	0.28	0.28	0.01	0.29	0.30	0.33	0.32	0.35	0.34
	B	0.14	0.14	0.13	0.13	0.12	0.13	0.14	0.14	0.13	-0.01	0.12	0.12	0.18	0.19	0.17	0.18
	C	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	-0.03	0.03	0.03	0.02	0.01	0.01	0.01
	D	0.23	0.22	0.20	0.19	0.24	0.24	0.22	0.21	0.21	-0.04	0.23	0.23	0.23	0.22	0.32	0.31
	E	0.41	0.39	0.35	0.33	0.45	0.44	0.39	0.37	0.37	-0.05	0.43	0.43	0.41	0.38	0.55	0.53
	F	0.12	0.13	0.10	0.11	0.11	0.12	0.12	0.12	0.11	0.01	0.10	0.11	0.18	0.19	0.23	0.23
	G	0.16	0.17	0.14	0.14	0.14	0.15	0.16	0.16	0.16	0.00	0.14	0.15	0.22	0.23	0.26	0.26
	H	0.26	0.25	0.21	0.21	0.27	0.27	0.25	0.24	0.24	0.03	0.26	0.26	0.31	0.30	0.40	0.39
	I	0.09	0.09	0.07	0.07	0.10	0.09	0.09	0.09	0.08	0.01	0.09	0.09	0.12	0.11	0.15	0.15
PRL	J	0.05	0.05	0.04	0.04	0.04	0.04	0.05	0.06	0.05	-0.03	0.04	0.05	0.04	0.04	0.01	0.01
	K	0.05	0.05	0.04	0.04	0.04	0.05	0.04	0.05	0.05	-0.02	0.04	0.05	0.07	0.07	0.06	0.06
	L	-0.04	-0.04	-0.03	-0.03	-0.04	-0.04	-0.04	-0.03	-0.03	-0.01	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04
	M	0.09	0.09	0.08	0.07	0.09	0.09	0.09	0.09	0.08	-0.02	0.09	0.09	0.06	0.06	0.01	0.02
	N	0.19	0.19	0.16	0.17	0.19	0.19	0.19	0.18	0.18	-0.01	0.18	0.18	0.24	0.25	0.23	0.23
	O	-0.10	-0.10	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	0.02	-0.09	-0.09	-0.15	-0.16	-0.15	-0.16
Urban	P	-0.38	-0.36	-0.31	-0.29	-0.42	-0.42	-0.36	-0.34	-0.33	0.18	-0.40	-0.40	-0.39	-0.36	-0.46	-0.44
	Q	-0.34	-0.32	-0.29	-0.27	-0.39	-0.39	-0.33	-0.30	-0.31	0.03	-0.38	-0.37	-0.33	-0.31	-0.39	-0.38
Farm	R	-0.04	-0.03	-0.03	-0.02	-0.04	-0.04	-0.03	-0.03	-0.03	0.01	-0.04	-0.04	-0.04	-0.03	-0.08	-0.08

Lithium Ion: lithium ion storage technology
NaS: sodium sulfur storage technology
VRB: vanadium redox storage technology
PHS: pumped hydro storage technology
CAES: compressed air energy storage technology
BTF: behind-the-fence site
PRL: price responsive load site