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Renewable Energy Generation and Storage Design for Remote Community of Rankin Inlet

1. Background

- There are 250 or so remote communities across Canada which are not connected to North America's integrated electricity grid, majority of them relying on diesel for electricity.
- Diesel serves to be a poor means to produce electricity due to its expensive costs and harmful environmental impacts.
- This project purposes an alternative energy system for the 100% diesel reliant community of Rankin Inlet, NU.

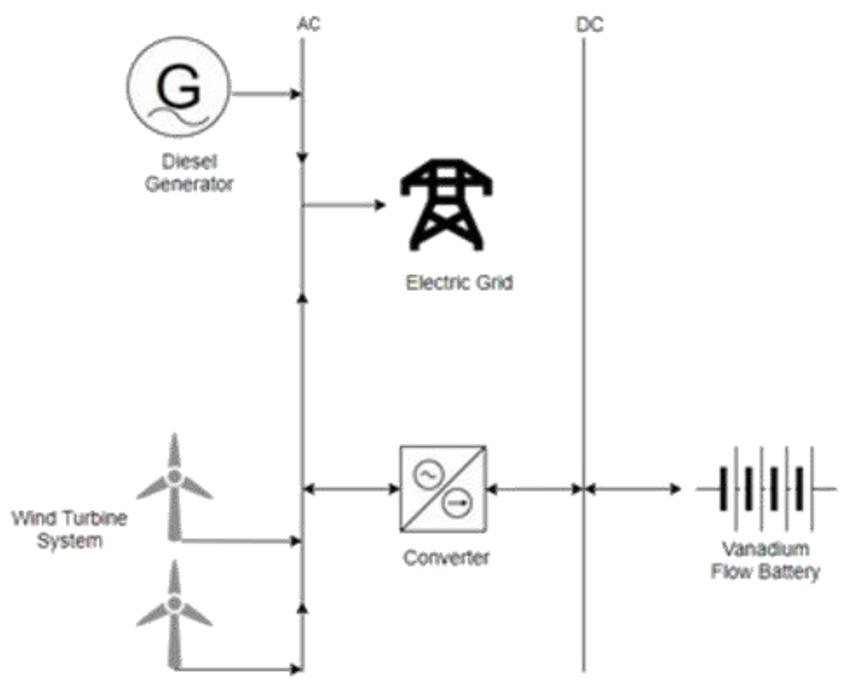

Figure 1: Integration of proposed energy generation and storage infrastructure.

2. Objectives

- The proposed energy system will incorporate renewable energy generation and storage systems to reduce Rankin Inlet's diesel dependency.
- The objective of the alternative energy system is to displace a minimum 40% of Rankin Inlet's diesel consumption and be economically comparable to the current system over a 20-year project life.
- The proposed project must fulfill the peak power demand of 3721.2 [kW] and support at least 16 hours' worth of backup (i.e., 95%) during the zero wind potential intervals.[1]

Annual Metrics of Current Diesel System:

Electricity Consumption [MWh]	Generator Capacity [kW]	Fuel Consumption [L]	Annual Cost [$]
17,625	4.11	4,685,914	7,660,770

3. Design Process

3.1. Renewable Energy Resources

- Wind was selected as the energy generation source due to its abundance and prior demonstration in similar projects.
- Solar generation was avoided due low potential limited daylight availability in Rankin Inlet.

3.2. Energy Storage Type

- Multiple types of electrochemical storage solutions were compared on basis of operating conditions, cycle life, capital and related operating costs.

4. Details of Design

4.1. Site Assessment

- Main criteria for the site assessment were to compare wind speed and regulatory restrictions to determine a low economic impact site.
- Different maps were developed using ArcGIS to aid in site selection by comparing geologic factors such as soil composition and terrain maps (finalized site being location A from figure below).

Figure 2: Sites analyzed for wind generation potential.

4.2. Turbine Selection

- Wind turbine selection was based off: wind turbine optimal speed range, wind turbine generating capacity (rating), cold climate operating technologies and wind turbine capital cost factors.
- The minimum turbine rating to achieve the defined project objective was estimated to be 2.69 [MW].

Evaluation and Selection of Different Turbine Configurations:

Turbine Model	Power Rating [MW]	Min. Operating Temp. [°C]	Cut-In Speed [m/s]	Optimal Speed Range [m/s]	Estimated No. of Turbines Required [-]
Enercon E70	2.3	-40	2.5	15 - 34	2
EWT DW54	0.9	-40	3	10 - 25	3

4.3. Vanadium Redox Flow Battery (VRFB)

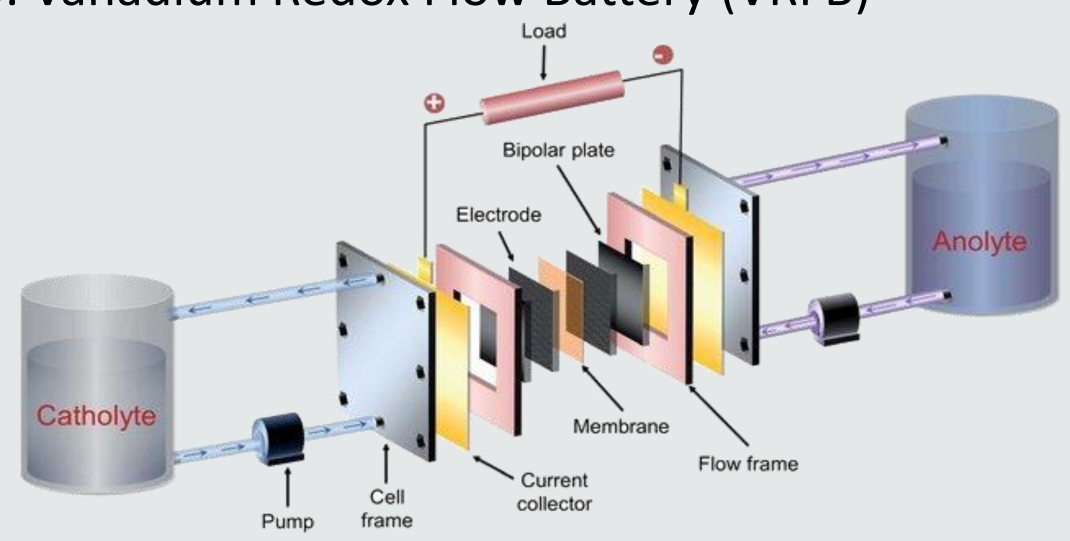

Figure 3: Schematic representing components used in construction of VRFB.[2]

$V^{2+} \rightleftharpoons V^{3+} + e^-$ $E^{\varnothing}_{anode} = -0.255$ [V]

$VO_2^+ + 2H^+ + e^- \rightleftharpoons VO_2^+ + H_2O$ $E^{\varnothing}_{cathode} = 1.004$ [V]

Net reaction(s): $V^{2+} VO_2^+ 2H^+ \rightleftharpoons VO_2 + V^{3+} + H_2O$

$E^{\varnothing} = E^{\varnothing}_{cathode} - E^{\varnothing}_{anode} = 1.259$ [V]

Key VRFB Metrics	Value	[Unit]
Energy capacity	32,168	[kWh]
Peak power	3,721.2	[kW]
Volume of each electrolyte	1,430	[m³]
Number of cells	5,016	[-]
Area of each cell	15	[m²]
Optimum Operating Temp. Range	10 - 40	[°C]

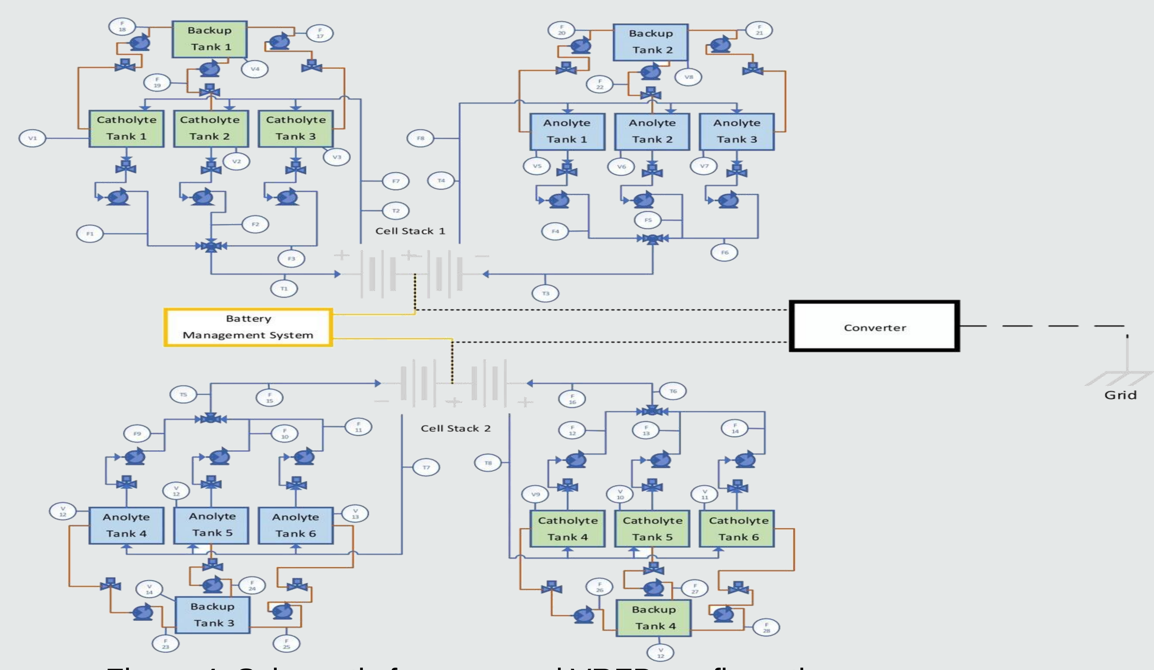

Figure 4: Schematic for proposed VRFB configuration

4.4. Simulation Results

- To simulate the performance of the proposed system with the shortlisted turbine configurations the software HOMER was utilized.
- Using wind resource, electric load, battery sizing and turbine data the Rankin Inlet microgrid was simulated

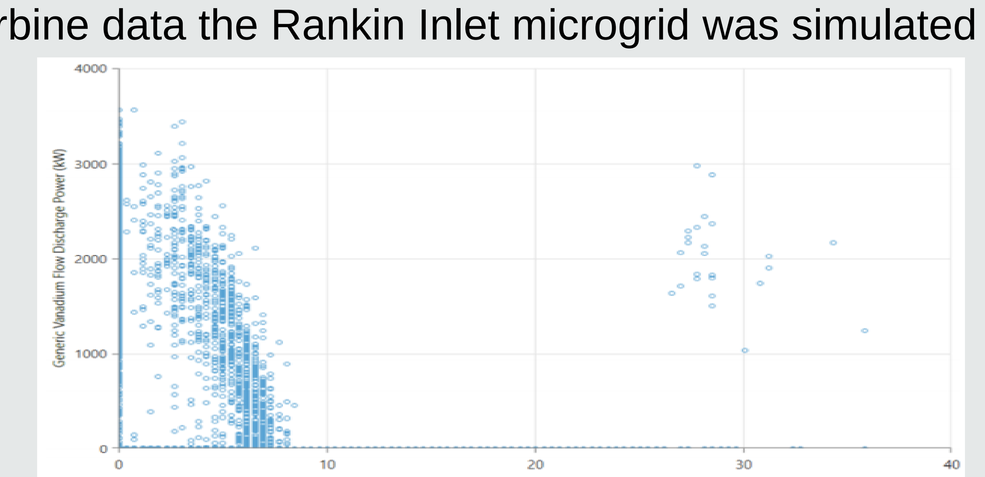

Figure 5: VRFB's discharge power vs wind speed.

	System Configuration	Production [MWh/year]	Excess Energy [%]	Total fuel [Million Lt]	Diesel Displacement [%]
Base Case	Generator	17625	0	4.69	0.0
Enercon E70	VRFB + Generator + 2 Turbines	24450	38.7	1.14	76.7
	VRFB + Generator + 1 Turbine	17993	0.05	2.48	50
	VRFB + Generator + 3 Turbines	18503	1.34	2.11	57.3
EWT DW54	VRFB + Generator + 2 Turbines	17721	0	2.96	41.0
	VRFB + Generator + 1 Turbine +	17634	0	3.82	20.9

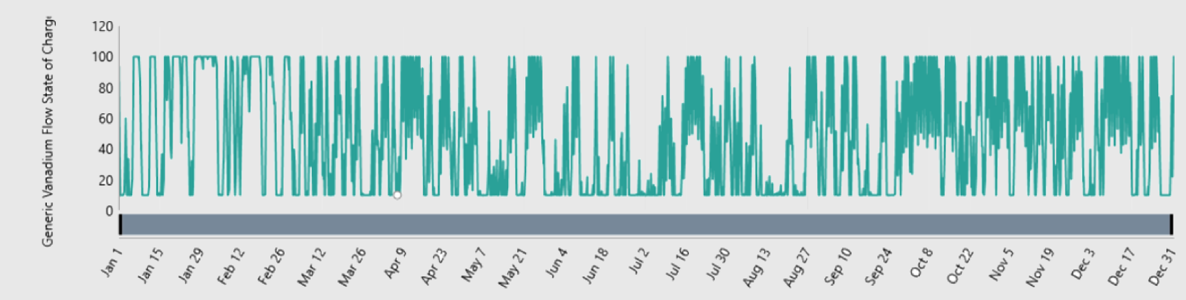

Figure 6: VRFB's annual state of charge (SOC) profile

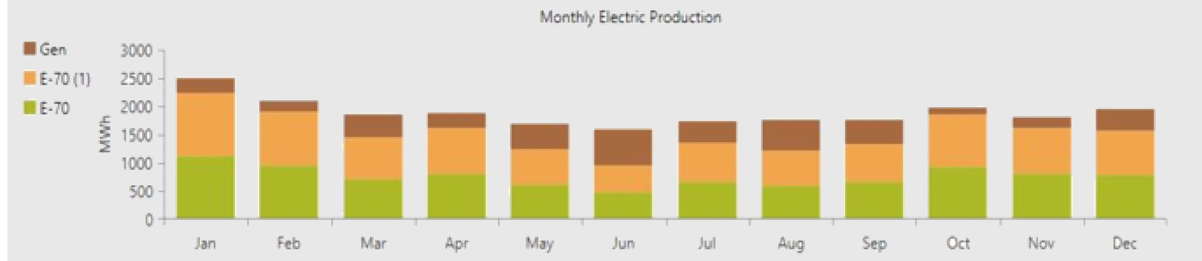

Figure 7: Annual profile of energy generation from turbines and generator.

5. Economic Analysis

The capital, O&M, overhaul and fuel costs for each system were compiled and evaluated over the project lifetime.

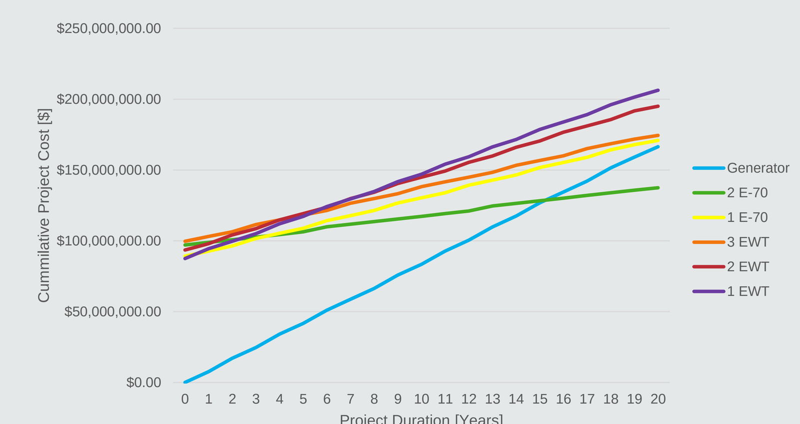

Figure 8: Cumulative cash flow the system achieves with different wind turbine configurations.

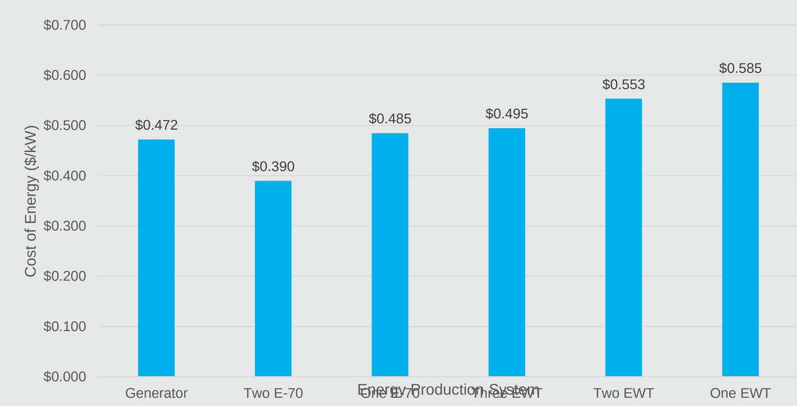

Figure 9: Levelized cost of energy for each system configuration.

6. Conclusions

- From the HOMER simulation results, it is apparent that the proposed system comprised of wind turbines and the VRFB can successfully achieve the project objectives.
- From simulation results, it is understood that the configuration of two Enercon E-70 wind turbines alongside a VRFB of 32,168 [kWh] provides the largest displacement of diesel fuel in Rankin Inlet at 76.7%
- From the economic analysis it is observed that this configuration reaches a payback period in about 16 years.

7. References

1. Wind potential data was retrieved from: https://climate.weather.gc.ca/climate_data/hourly_data_e.html?hlyRange=2013-03-12%7C2021-02-19&dlyRange=2013-03-14%7C2021-02-19&mlyRange=%7C&StationID=51277&Prov=NU&urlExtension=_e.html&searchType=stnName&optLimit=yearRange&StartYear=2015&EndYear=2021&selRowPerPage=25&Line=0&searchMethod=contains&Month=2&Day=19&txtStationName=rankin+inlet&timeframe=1&Year=2021

2. Image retrieved from Kim, K. J., Park, M. S., Kim, Y. J., Kim, J. H., Dou, S. X., & Skyllas-Kazacos, M. (2015). A technology review of electrodes and reaction mechanisms in vanadium redox flow batteries. *Journal of materials chemistry a*, *3*(33), 16913-16933.

8. Acknowledgments

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