Hybrid Offshore Wind-Seawater Desalination System

Jessica Fischer, State University of New York at Canton
Dr. Matthew Lackner, University of Massachusetts Amherst

Background

Many developing island nations and coastal communities struggle to produce basic resources and services such as energy and clean water. These locations typically rely on fossil fuels for primary energy production as well as seasonal rainfall as a source of water for drinking and agriculture. While energy and water systems are interconnected, existing approaches address these issues independently.

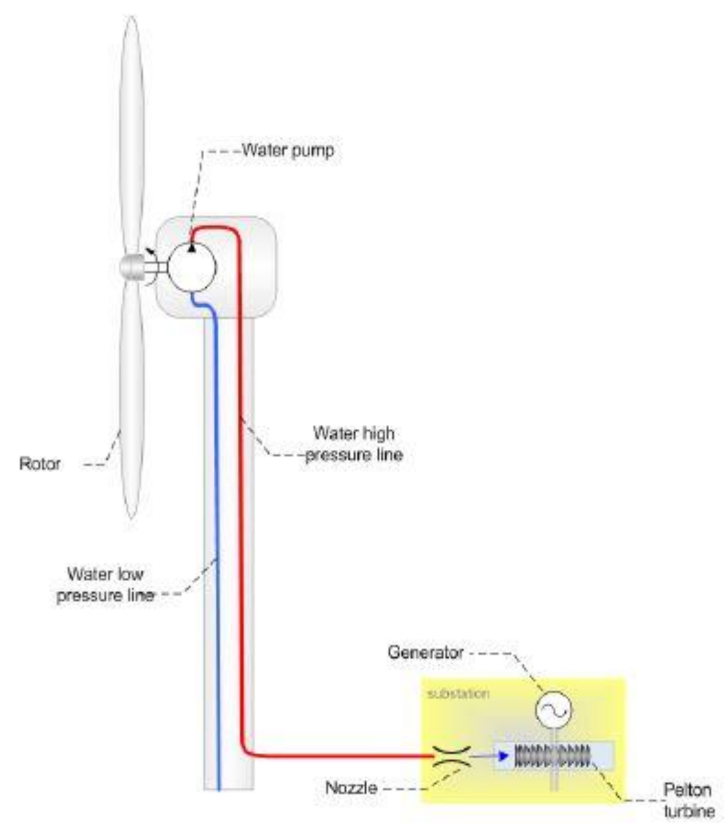
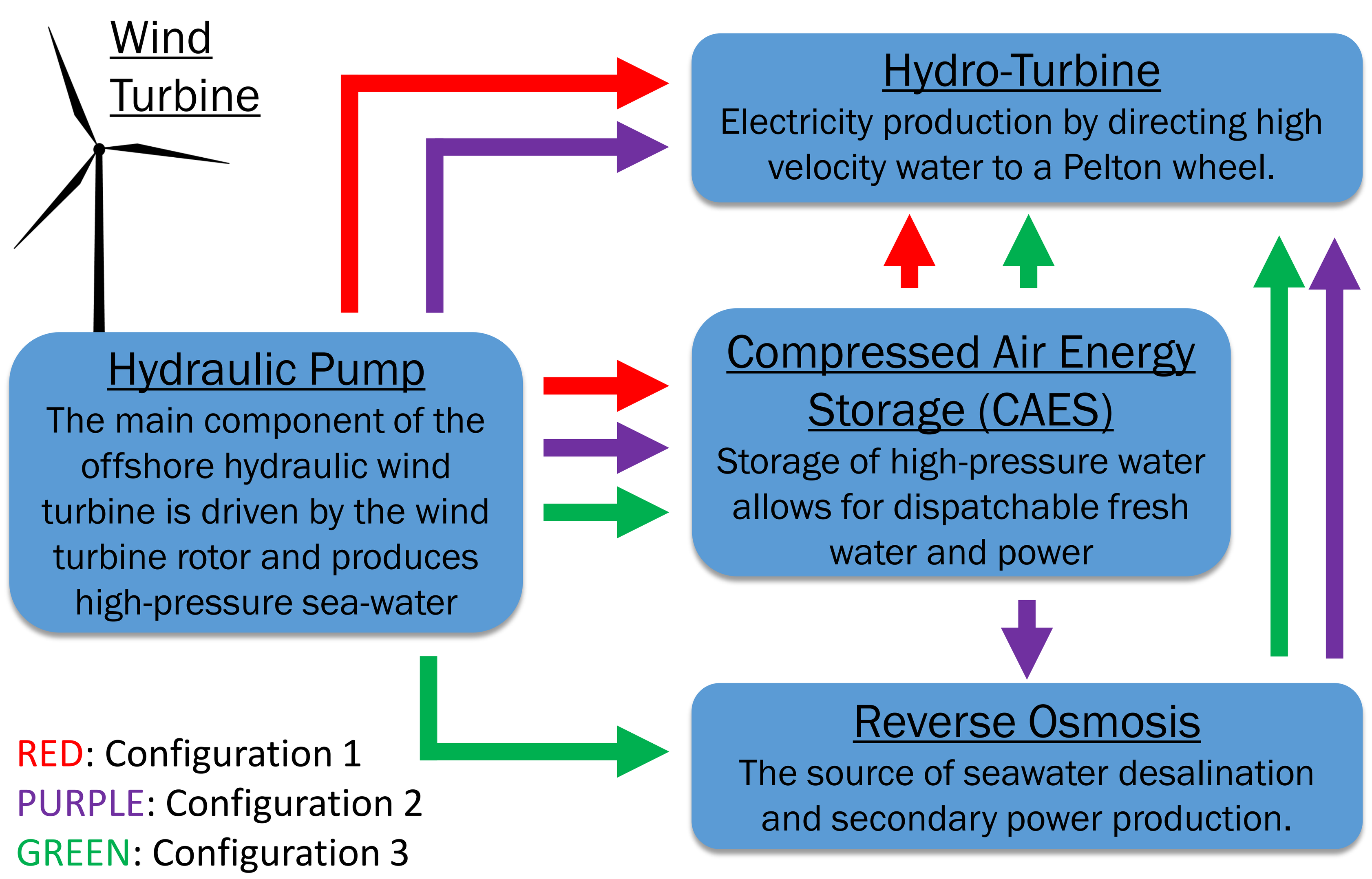


Figure 1: hydraulic wind turbine [1]

An alternative approach is to utilize renewable energy sources for energy generation, and to couple the production of fresh water and energy in a hybrid system. This work will consider a novel hydraulic wind turbine (Figure 1), which is well suited to coupling electricity production with seawater reverse osmosis (RO) desalination.

System Design



Project Objectives

- Develop a hybrid wind energy-storage-reverse osmosis model in MATLAB
- Simulate a variable wind input to the model, and control the system to produce constant power output.
- Identify necessary equipment required for experimental model validation
- Experimentally demonstrate the behavior of storage and power production in the lab

Results and Discussion

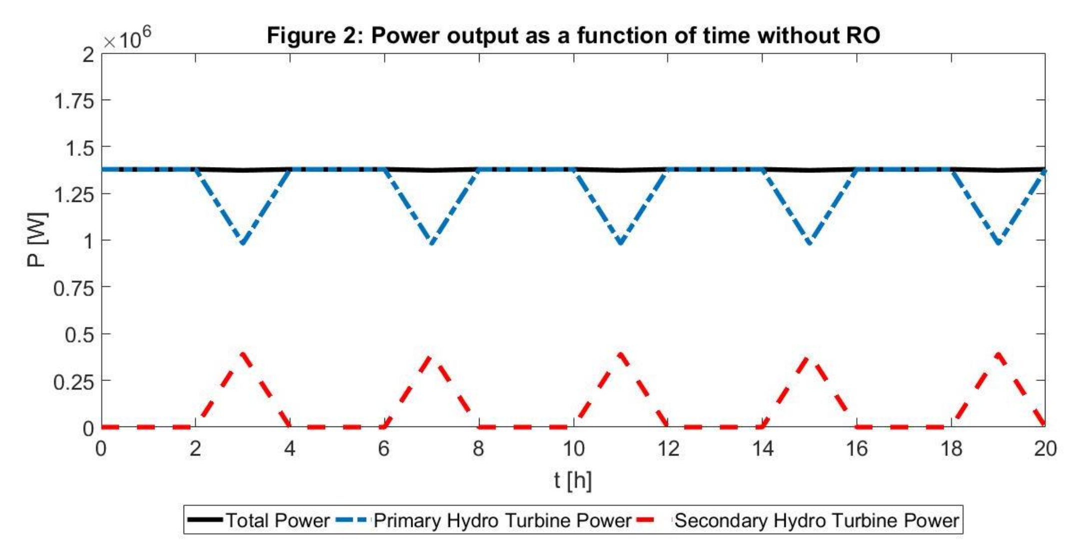
A time-varying wind speed signal was produced, with a 7-9 m/s wind speed range, assuming a 5-MW wind turbine. The MATLAB model calculates power outputs and fresh water flow rates for a given system configuration. Three system configurations were considered: (1) – No RO; (2) RO located after CAES and before secondary hydro turbine; (3) RO located before primary hydro turbine.

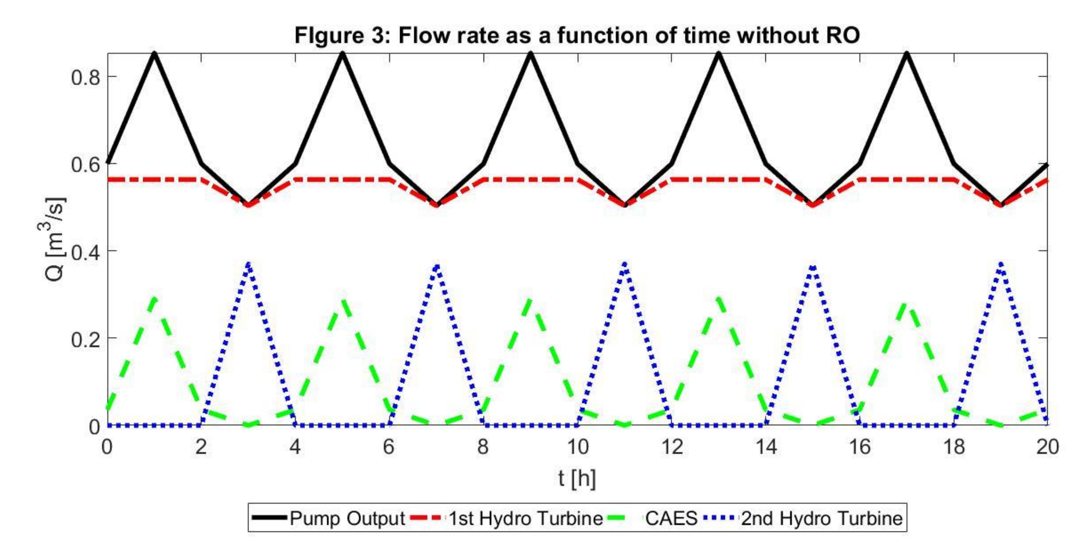
The system is controlled by adjusting the flow rates within the system at any given wind speed. The goal is to produce constant power through time, while constraining the CAES system to equal total inflow and outflow (i.e. no accumulation).

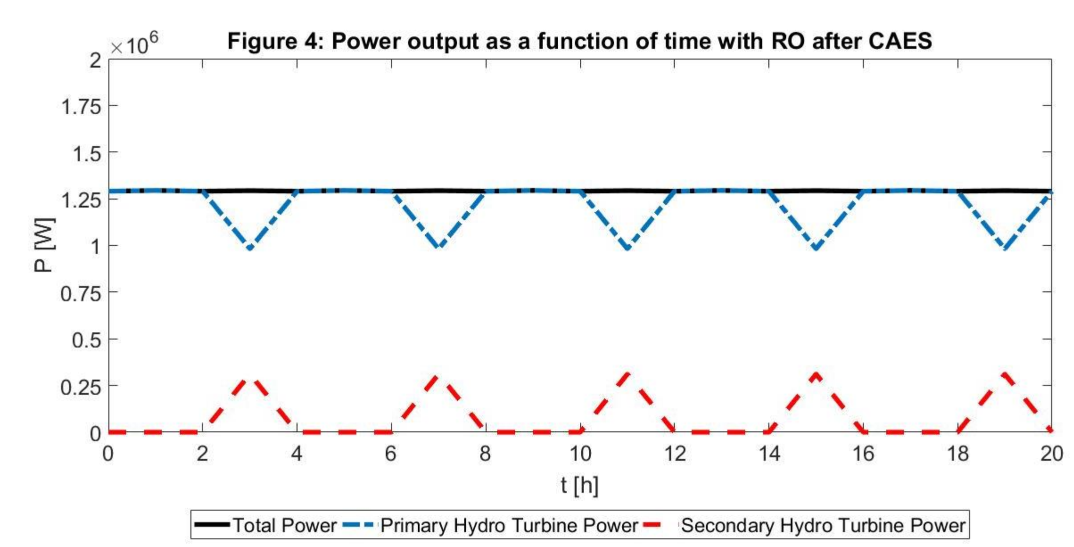
Figures 2-7 show the results for the three configurations.

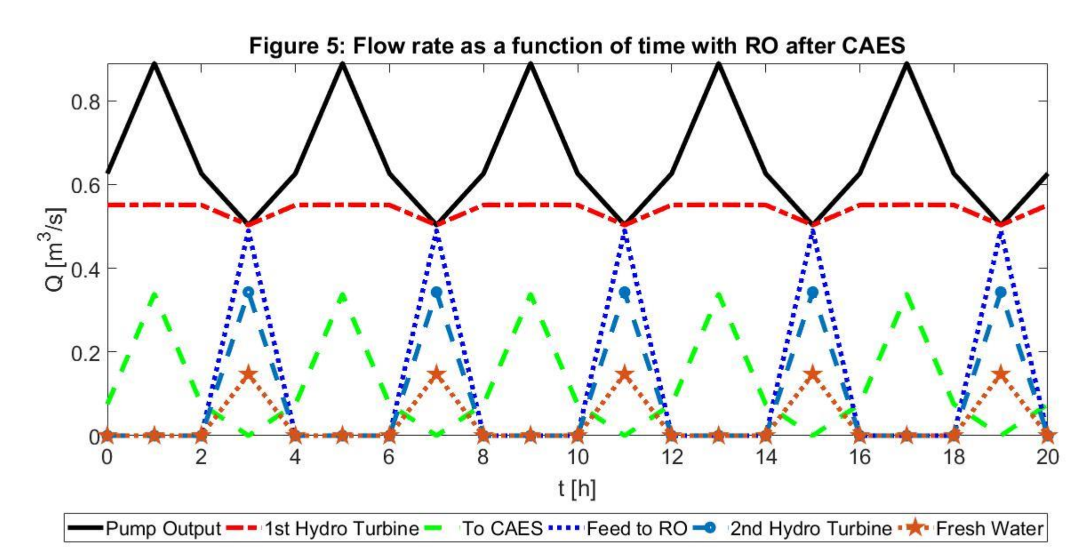
- For all cases, constant power can be achieved by charging the CAES during high wind speeds (net flow in), and discharging (net flow out) during low wind speeds to the secondary hydro turbine
- As RO is included and fresh water production increases, the overall power output decreases.
- The case for maximum power production is when there is no RO in the system (configuration 1). The case for maximum fresh water production is when the RO system is in line with the primary hydro turbine (configuration 3); this is due to a higher flow rate through the RO system.

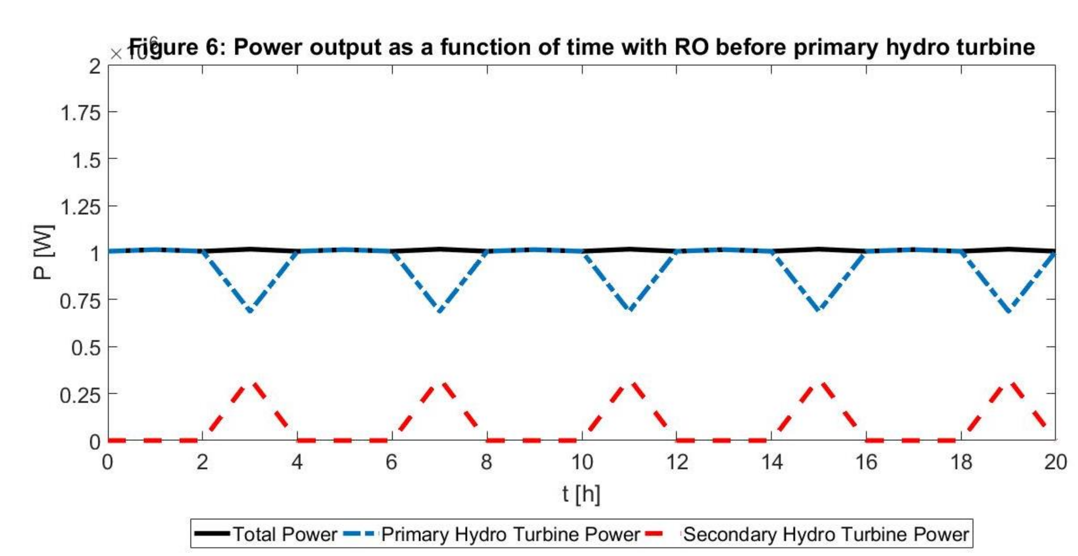
Figure 8 compiles the trade off between power loss and fresh water production.

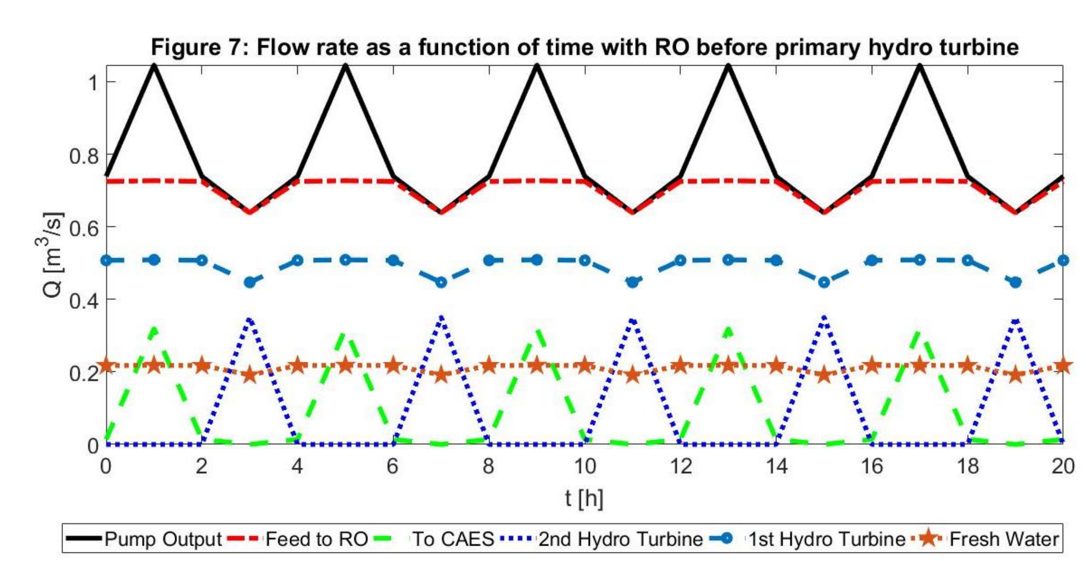


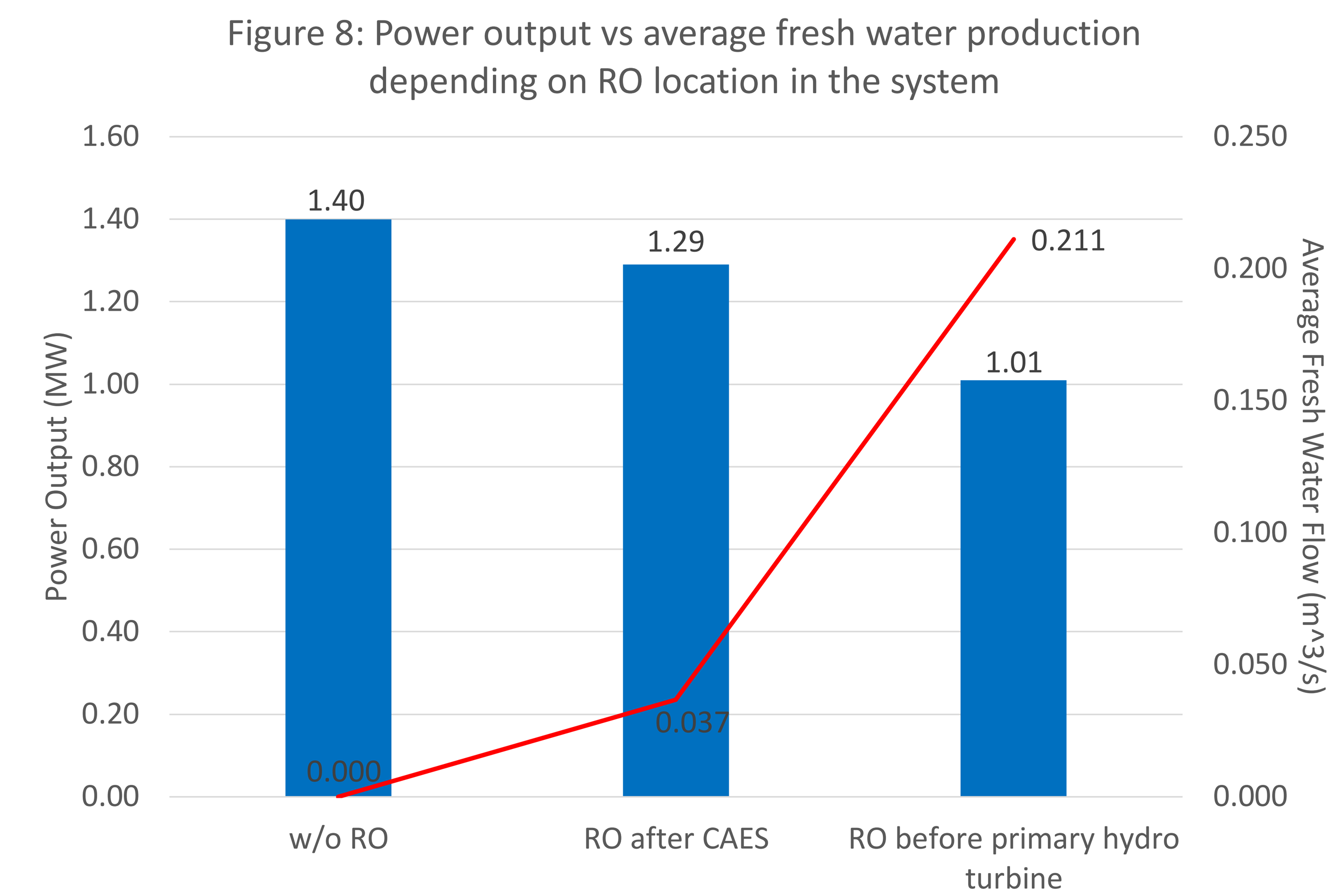












Experimental Demonstration

Equipment was selected to verify the findings in the MATLAB model. Selection parameters were determined by pressure and flow rate limits of the available equipment from McMaster-Carr. Fittings and gauges were limited to availability at Home Depot. Tests included identifying the effect of fluctuating flow rates on a Pelton Wheel hydro turbine, identifying the behavior of CAES and its relation to flow rates, and behavior of the system with varying percentages of flow directed toward each main component. Reverse osmosis was not part of the initial testing.

Future Work

The results of this project will be a baseline model for future developments of the hybrid system. Future work will include:

- Utilizing only one hydro turbine in the system
- Analyzing effects of parallel vs. series RO locations
- Adding water treatment to the model
- Introducing photovoltaics as a secondary power source
- Investigating RO as a component of the experimental system

Acknowledgements

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References

1. Supper, M. F. (2017) Fluctuating flows on reverse osmosis membranes: an experimental approach for hydraulic dive train wind turbine applications.