Optimizing Power Reclamation of Micro Hydro Turbines in WWTPs Aeration Basins

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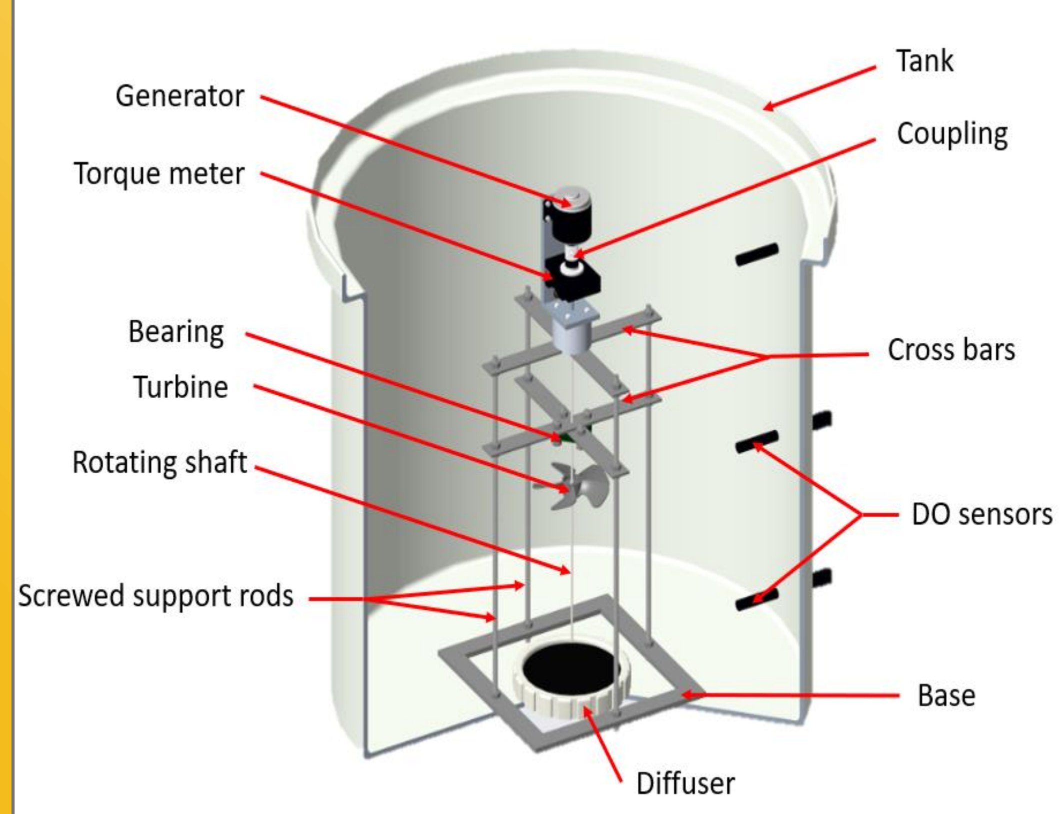
Introduction

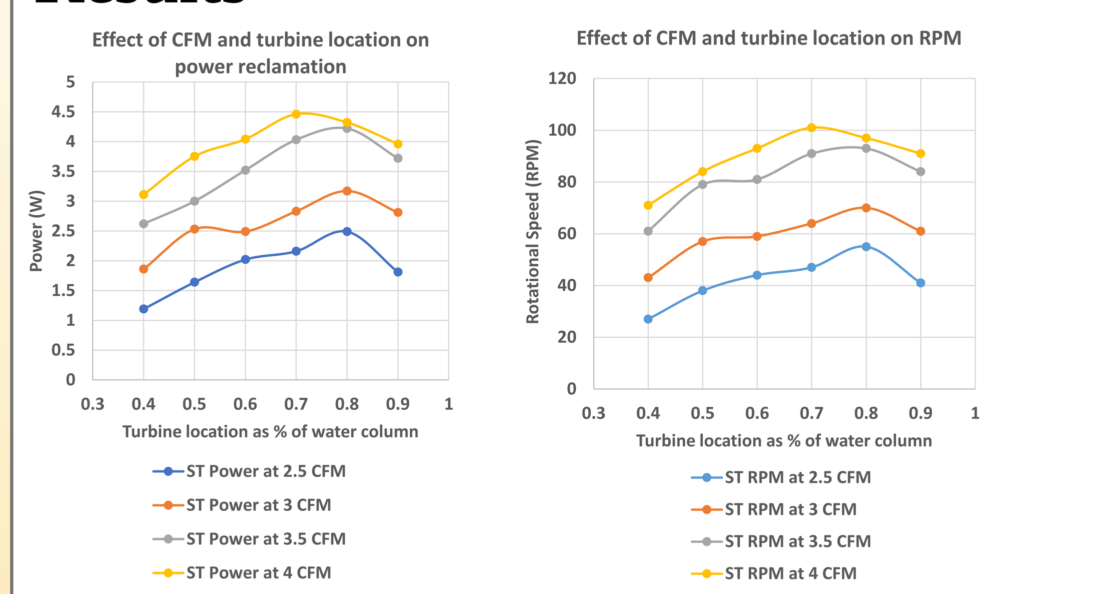
There are more than 15,000 publicly owned Wastewater Treatment Plants (WWTPs) nationwide, with electricity costs representing 25 to 40% of their total budget, WWTPs are considered one of the most significant energy-consumer sectors in the US [1]. WWTPs consume about 4% of the total energy consumption in the U.S each year. Therefore, trimming the operation costs is always a priority for WWTPs, while improving effluent quality and meeting temperature standards should be achieved simultaneously [2,3].

In a typical WWTP, the aeration system uses between 40 and 60% of the plant's total energy consumption. Nationwide, more than $4 billion are spent annually on WWTPs' electrical bills. Therefore, any minimal energy-saving or energy-reclamation solution is considered as a significant reduction in the energy costs of municipalities across the country if the proposed solution is implemented extensively [4].

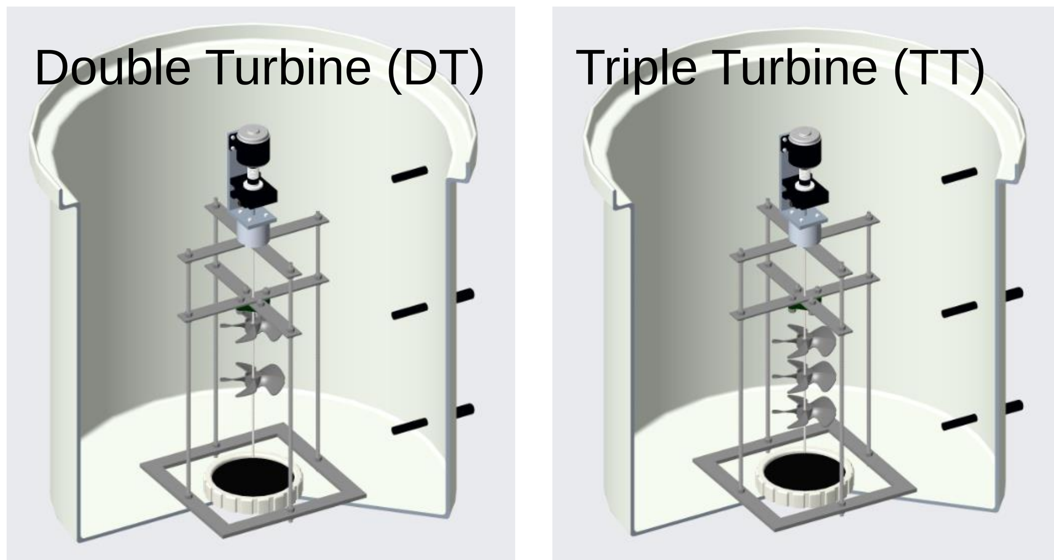
Methodology



Results



The range of power reclamation of a single turbine increases with the increase of introduced CFM. For all airflows, power maximizes at turbine location of 80% of water column. The change in power is directionally proportional to the change in RPM.



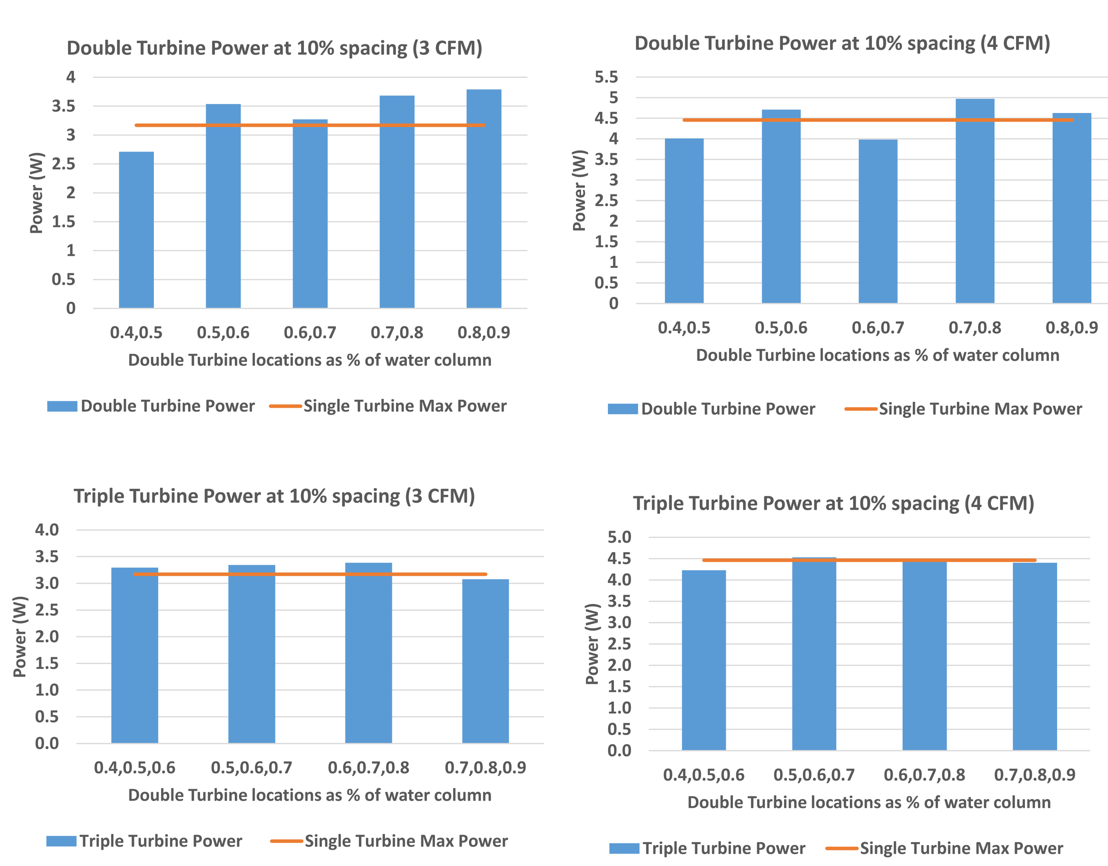
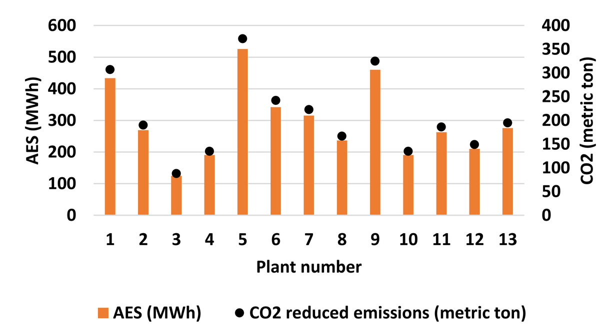


Table 1: The percentage of double turbine's power increase (or decrease) over a single turbine's maximum power reclamation.

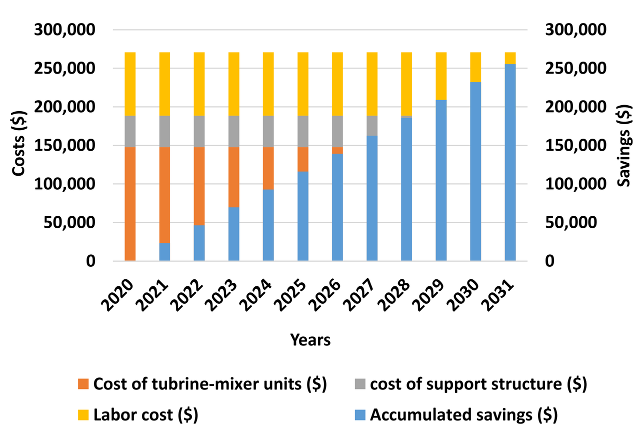
Spacing (% of water column) = 10%						
Airflow (CFM)	Locations (% of water column)	0.4,0.5	0.5,0.6	0.6,0.7	0.7,0.8	0.8,0.9
3	DT Power (W)	2.71	3.54	3.27	3.68	3.79
	% increase or decrease	-14.51	11.55	3.22	16.22	19.59
4	DT Power (W)	4.01	4.71	3.98	4.98	4.63
	% increase or decrease	-10.09	5.64	-10.74	11.57	3.82
Spacing (% of water column) = 20%						
Airflow (CFM)	Locations (% of water column)	0.4,0.6	0.5,0.7	0.6,0.8	0.7,0.9	
3	DT Power (W)	3.33	3.58	3.68	3.69	
	% increase or decrease	5.05	12.93	15.93	16.48	
4	DT Power (W)	4.48	5.12	4.67	4.53	
	% increase or decrease	0.45	14.87	4.82	1.54	
Spacing (% of water column) = 30%						
Airflow (CFM)	Locations (% of water column)	0.4,0.7	0.5,0.8	0.6,0.9		
3	DT Power (W)	3.39	3.70	3.75		
	% increase or decrease	6.91	16.73	18.27		
4	DT Power (W)	4.56	4.91	4.86		
	% increase or decrease	2.21	10.11	8.95		
Spacing (% of water column) = 40%						
Airflow (CFM)	Locations (% of water column)	0.4,0.8	0.5,0.9			
3	DT Power (W)	3.73	3.53			
	% increase or decrease	17.67	11.50			
4	DT Power (W)	4.87	4.76			
	% increase or decrease	9.09	6.78			
Spacing (% of water column) = 50%						
Airflow (CFM)	Locations (% of water column)	0.4,0.9				
3	DT Power (W)	3.59				
	% increase or decrease	13.35				
4	DT Power (W)	4.55				
	% increase or decrease	2.12				

Table 2: The percentage of triple turbine's power increase (or decrease) over a single turbine's maximum power reclamation.

Spacing (% of water column) = 10%					
Airflow (CFM)	Locations (% of water column)	0.4,0.5,0.6	0.5,0.6,0.7	0.6,0.7,0.8	0.7,0.8,0.9
3	TT Power (W)	3.29	3.34	3.39	3.08
	% increase or decrease	3.89	5.46	6.80	-2.96
4	TT Power (W)	4.23	4.53	4.44	4.40
	% increase or decrease	-5.23	1.57	-0.55	-1.32
Spacing (% of water column) = 20%					
Airflow (CFM)	Locations (% of water column)	0.4,0.6,0.8	0.5,0.7,0.9		
3	TT Power (W)	3.81	3.57		
	% increase or decrease	20.24	12.73		
4	TT Power (W)	4.76	4.48		
	% increase or decrease	6.76	0.52		



The implementation of the proposed project in the 13 WWTPs assessed by the UWM-IAC results in a considerable energy saving, hence significant CO2 emission reduction.



This figure shows how the project would recoup its initial investment in 11 years for plant (2). Annual energy savings accumulate over years to cover the capital cost by the advent of 2031.

Conclusions

- The highest velocity is obtained in the upper half of the water column (70% - 80%), while the lowest velocities were obtained just above the air diffuser and at the water surface.
- It's recommended to install the micro-propeller at the locations of the highest velocity to harness the high momentum at this region and therefore maximizing the power reclamation.
- The reclaimed power is directly proportional to the diffuser air flow.
- The power reclamation change is directly proportional to the RPM change, since the torque is almost constant through all test (the same generator load is attached to the torque sensor for all tests)
- The range of power reclaimed at 4 CFM is higher than its counterpart at 3 CFM.
- Using DT and TT instead of ST resulted in an increase in the power reclamation. The maximum percentage of increase in power reclamation for DT is 19.59%, while it is 20.24% in case of TT.
- The implementation of the proposed project in the 13 WWTPs assessed by the UWM-IAC results in annual considerable energy savings that reaches 500 MWh in plant (5), that leads to annual cost savings of $30,000, hence significant CO2 emission reduction that exceeds 370 metric tons in the same plant.

Future work

- CFD simulations should be performed to obtain plant-scale model that will help with more accurate evaluation of the annual energy savings in a real WWTP.
- The effect of using different diffusers on power production and SOTE (porous and sharp nub, in addition to the tested membrane diffuser)

Sharp-Nub Ceramic Membrane

Literature cited

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Acknowledgments

The team acknowledges the DOE's support that came in the form of the "Industrial Assessment Center Award for Excellence in Applied Energy Engineering Research competition" that the team was awarded in August 202.

Many thanks to UWM CEAS for providing lab facilities, to Prof. Amano and teammates for support, and cooperation.

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