ENGR10004 Engineering Systems Design 1 Design Project
Water Pumping and Storage Specifications

1 Summary

This document presents the detailed specifications for the water pumping and storage module of the semester long team design project for Engineering Systems Design 1. This project involves the planning, design, construction, testing and reporting of a solution to a real-world design problem involving the pumping and delivery of water to a remote community using renewable energy resources.

The proposed project involves the planning, modelling, design and testing of a small wind-powered pumping station to supply drinking water to a remote community from an underground well - see Figure 1. Wind energy will be harnessed via a wind turbine, which converts the mechanical energy provided by the wind into electrical energy to drive the pump in the underground well. The water is pumped through a pipe and stored in an above-ground tank that has a spout and tap on the bottom to allow people to obtain water via gravity-driven flow. This configuration with an above-ground tank is important because if a pump fails or no power is available, water can still be obtained for some time simply via gravity. There are periods when there is little or no wind power and energy storage system will be employed, but this is being designed and sized by an external engineering firm that specialises in this area. To improve the quality of the drinking water, the water will be treated by a small ozone generation and disinfection system. The process for completing the water pumping and storage section of the design project will consist of :

- Experiment
- Modelling
- Design
- Testing

Note that this document is a only a sub-module of the complete water-pumping design project. Refer to the complete project specifications for an overview of the project and description of the overall subject requirements.

A check list of the tasks to be completed for this module of the design project are summarised at the end of this document.

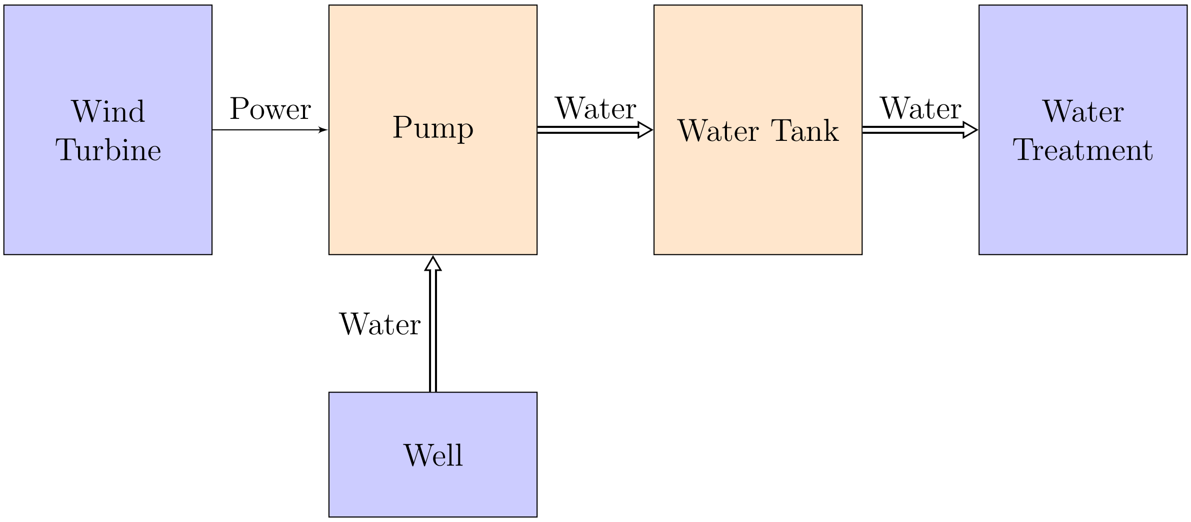

Figure 1: Wind Powered Pumping Station Systems Diagram

2 Introduction

An above-ground gravity driven storage system is to be employed in order to deliver drinking water to the remote community as shown in Figure 2. In this scheme, an underground pump pumps clean water from the 35m underground well into an above-ground tank via a concrete pipe. The tank is housed on a sturdy but simple support structure 10 m off the ground. An outlet on the bottom of the tank then supplies water via a basic tap valve. In this system, the water flows out of the tank due to gravity, which keeps the system relatively simple and has the benefit of offering a limited water supply in the case of a pump failure or power outage. Housing the tank some distance above the ground also prevents it from being contaminated or interfered with by humans.

The tank comprises of an inlet at the top, an outlet on the bottom and a couple of sensors that detect when the fluid level in the tank is high or low as shown in Figure 3. The sensors connect or disconnect the pump from the power supply (i.e. wind turbine or stored energy system) through a control module depending on the level of the water as shown in Figure 4. Note that this is not a one-to-one mapping, but employs *hysteresis*, where the state of the pump (i.e. OFF or ON) depends not only on the current water level but also on if the level is decreasing or increasing. Hysteresis is intentionally added to the pump system to prevent unwanted rapid switching if only a full sensor was used and regular but low volume amounts of water were taken from the tank.

Modelling the tank requires an accurate knowledge of the geometry of the tank and a value for the *orifice coefficient*, denoted as C_D, which models the behaviour of fluid through the outlet. This value is usually determined empirically, that is from experiment, due to it being highly dependent on the geometry of the tank outlet and thus difficult to calculate from theory.

The pump is a submerged unit and sits well below the ground surface. Knowing the pump's power characteristics is vital in coupling it to the wind turbine unit. Both of

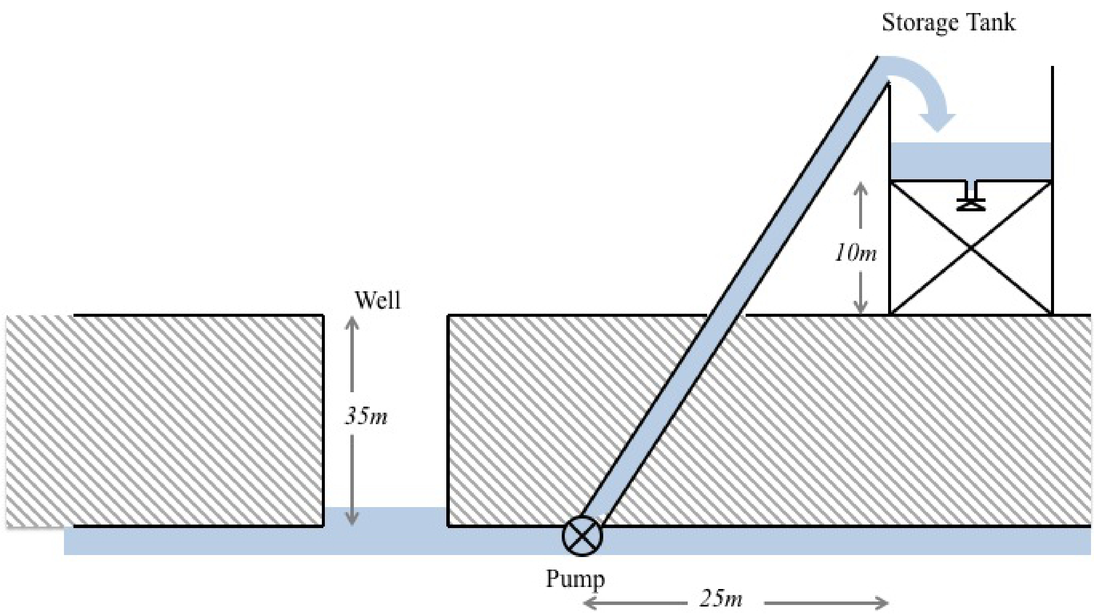

Figure 2: Pumping and water storage system

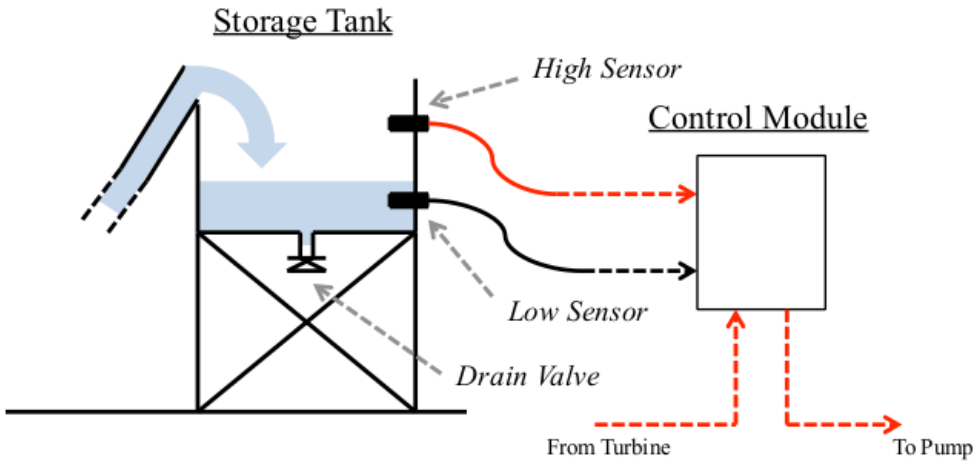

Figure 3: Tank system showing sensors and control system

these units must be able to generate enough power to run the pump, which must also have enough power to pump the water to height of the tank on the support structure. The flow rate the pump can deliver is also important and must take into account the size of the tank, the drainage characteristics of the tank, and the expected need for drinking water for the community.

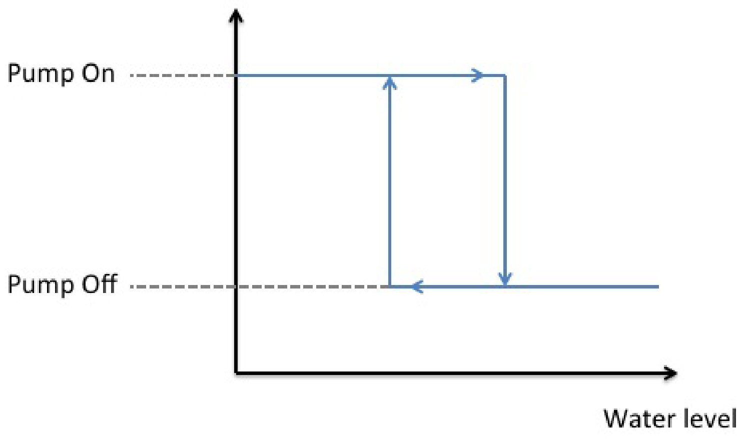

Figure 4: Operation of the pump for different water levels

3 Experiment

3.1 Determining the discharge coefficient C_D

Include your experimental work from Workshop 3, including a description of the experimental procedure, results and any required MATLAB plots showing how your value of C_D was obtained.

Note : You must use your value of C_D obtained from experiment in your tank design.

3.2 Determining the pump flow rate Q

Include your experimental work from Workshop 4, including a description of the experimental procedure, results and any required MATLAB plots. You need to show that the model you created for the experimental rig matches what is shown experimentally.

3.3 Measuring the pump power

Include your experimental work from Workshop 4, including a description of the experimental procedure, results and any required MATLAB plots. You must estimate a value for the pressure head H_p of the pump on the rig.

4 Designing the water pumping and storage system

After gaining a basic understanding of the effects of input voltage, pump power and flow rate on pumping water through the rig experiments, your goal is now to design the water pumping and storage system for the real-world design problem. Your model will be implemented in MATLAB and will serve as verification that your design meets the appropriate goals via simulation.

4.1 Tank

Once you have a working MATLAB model of the tank on the experimental rig, it's now time to design one for the real-world design problem, model it and use your model to validate its performance in MATLAB. You will need to choose the tank's

- Shape
- Size
- Material
- Sensor (empty and full) locations
- Orifice size

in order to satisfy the drinking water needs of the local population. You are constrained by the measurements and setup in the diagram given in Figure 2 (including the requirement that the pipe fills the tank from the top and that the pipe is made from concrete). All equations used in the modelling of the tank must be listed and any expressions derived must be shown. Any assumptions or choices you make in order to complete your design must be justified. You will likely have to do research to find the relevant theory, any figures or data you may need to back your design as being a valid solution to the design project.

Note : You must use your value of C_D obtained from experiment in your tank design.

Some things to think about

- Expected daily drinking water usage
- Expected lifespan of the tank and taking into account population growth
- Reserve capacity of water (if pump out of service)
- How long to fill the tank if empty

4.2 Pump

You will need to choose the pump's

- Flow rate Q
- Specific work W_s

Some things to think about

- Expected power available from wind turbine
- How long to fill the tank if empty (flow rate)

4.3 Pipe

You will need to choose the pipe's

- Diameter
- Total length

Note that the pipe is made out of concrete, which will require estimating a friction factor based on the roughness ratio (assuming turbulent flow). Some things to think about

- How long to fill the tank if empty (pipe diameter)
- Assumption of turbulent flow valid?

5 Checklist

Use Table 1 to ensure that you have completed the necessary tasks for each part of the experiment and design process. Once you have completed these tasks, you should have enough information to compile your final group project report for the water pumping and storage module.

Phase	**Task**	**Completed**
Experiment	Perform C_D experiment	☐
	Perform pump flow rate experiment	☐
	Perform pump power experiment	☐
Tank Design	Select shape of tank	☐
	Select size of tank	☐
	Select material of tank	☐
	Select sensor locations of tank	☐
	Select orifice size of tank	☐
	Model tank operation for "typical" conditions in MATLAB	☐
Pump Design	Select appropriate flow rate for pump	☐
	Select appropriate specific work W_s for pump	☐
Pipe Design	Select appropriate diameter for pipe	☐
	Select appropriate total length for pipe	☐

Table 1: Checklist of required tasks in order to complete the water pumping and storage system module of the design project