Memorial University of Newfoundland:
Faculty of Engineering and Applied Science

ENGI 7856: Renewable Energy Systems

LAB 2: Model and simulate a small wind turbine with resistive and battery load in Simulink

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1.0 Introduction

The goal of the lab is to model and simulate a small wind turbine with a resistive and battery load in Simulink.

2.0 Description - Modeling

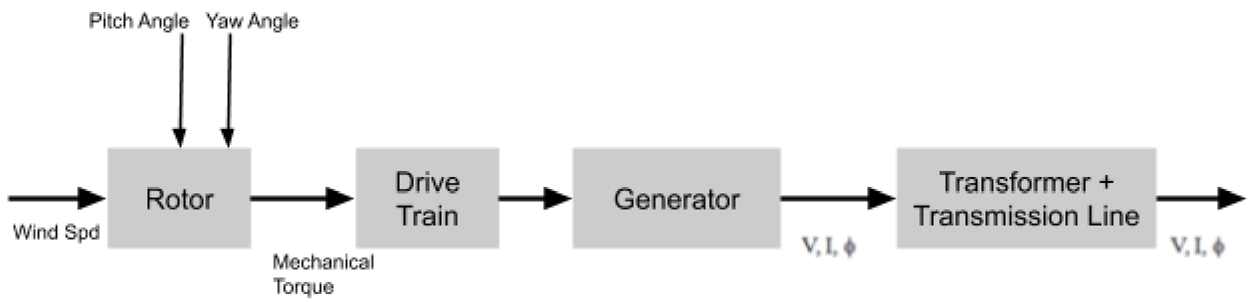


Figure 1: Wind Turbine Dynamic Model

2.1 Rotor

Modeling from equation the rotor model equation [lecture 5, slide 6]. This simple model ignores the tower, nacelle, flapping, and tilt angles.

$$T_{WT} = 0.5\rho\pi R^3 C_q(\lambda_1 \beta)\ \ u^2 cos^2\theta\ \ [N \cdot m]$$

where T_{WT} ; Rotor Torque
ρ ; Air Density
R ; Rotor Radius
C_q ; Torque Coefficient
λ_1 ; Tip Speed Ratio
β ; Rotor Pitch Angle

u ; Wind Direction
θ ; Yaw Angle

This formula along with $C_p - \lambda$ curves from a selected wind turbine forms the basis for a rotor turbine model.

2.2 Drive Train

A simple first order drive train model. Where each equation term respectively represents the wind turbine energy, the friction, and the gearbox ratio multiplied by generator torque.

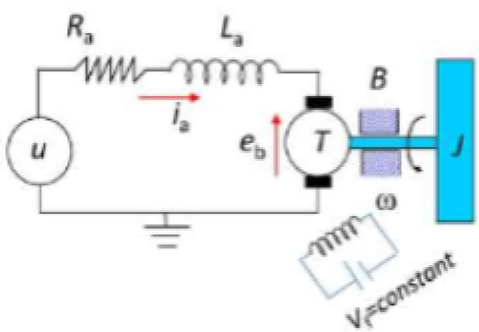
$$T_{WT} = J\frac{dw_n}{dt} + \beta\omega_n + NT_e$$

J ; Wind Turbine Energy
β ; Friction Coeff.
N ; Gearbox Ratio
T_e ; Generator Torque

2.3 Electrical

2.3.1 Generator

Simple 2nd order model for a DC motor/generator.



Torque-Current: $T_{motor} = K_t i_a$

Voltage-Speed: $e_b = K_b \omega$

$$L_a \frac{di_a}{dt} + R_a i_a + K_b \omega = u$$

$$J\dot{\omega} + B\omega - K_t i_a = 0$$

2.3.1 Advanced Modeling

The following can also be modeled for more advanced accurate systems. Each model can always be improved with better data or design specific implementation such as individual gears and couplings for mechanical models.

- Transformer & Transmission Line
- Inverter Model
- Battery Charger / Storage

2.3 Basic Model

To ensure our turbine model was operating correctly, we first simulated the turbine used in the example video.

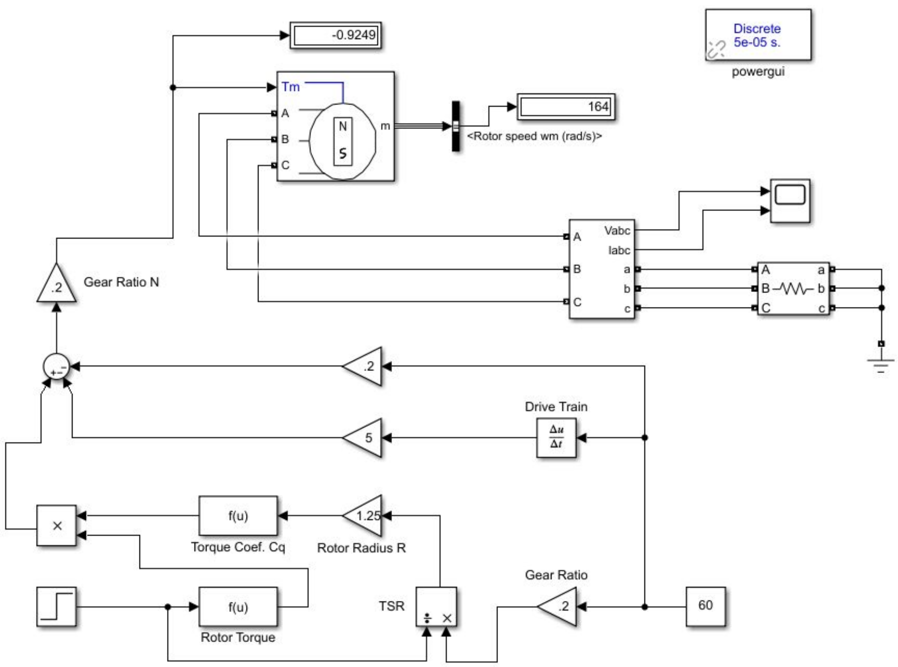


Figure 3: Example simulation modeled.

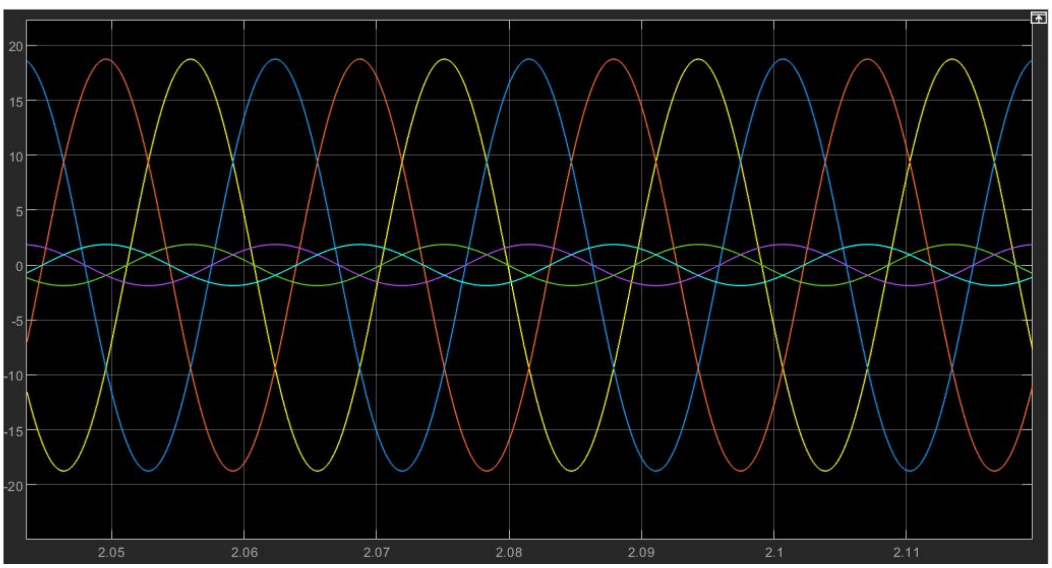


Figure 4: Example simulation turbine waves, similar to video.

2.3 Wind Turbine Selection

https://istabreeze.us/i-2000w-48v-windsafe-wind-turbine/

Selected the ISTABREEZEi-2000W 48V for our turbine. We used the values from the datasheet as follows R = 1.1m, Gear Ratio N =0.18. It has a AC 3-phase permanent magnet generator which works in our simulation. The Cq curve was generated from the opensource tool in the lecture notes Wind Turbine Rotor Analysis from umass.org

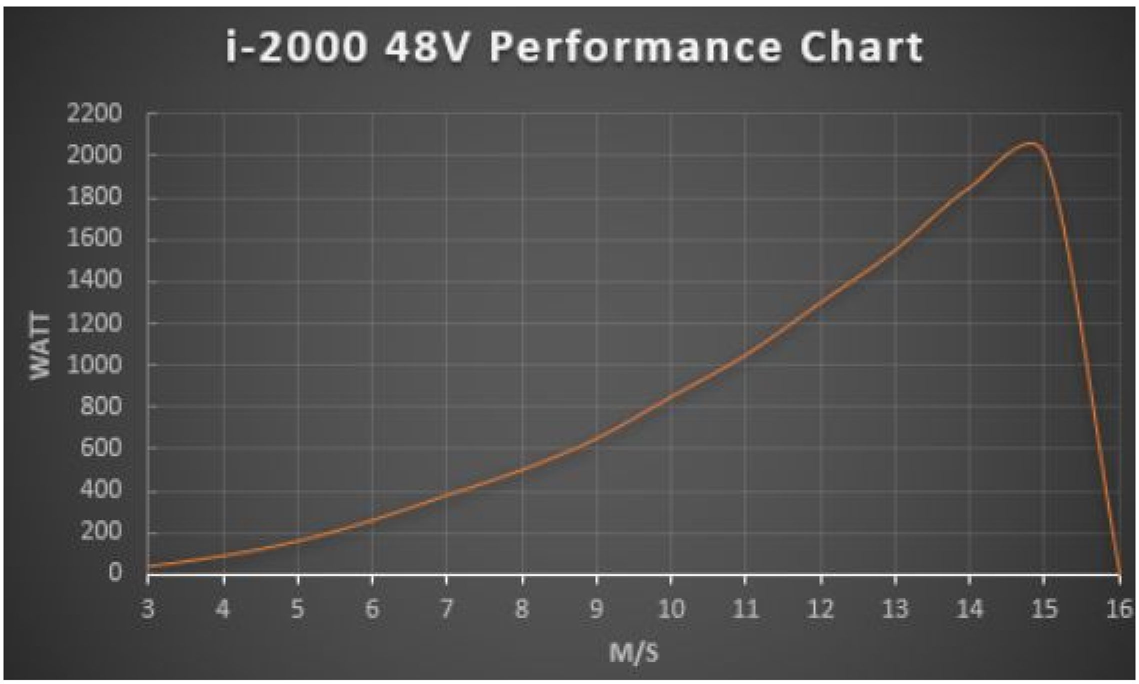


Figure 2: Bergey Excel-15 Turbine Power Curve

2.0 Resistive Load Model 1

Model 1 with resistive load, see simulation.

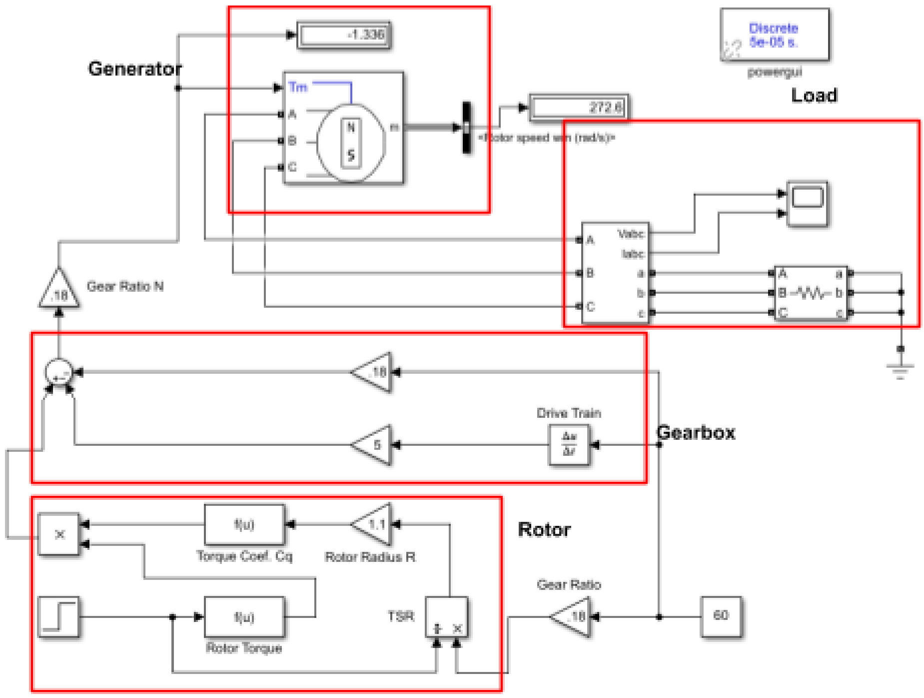


Figure 5: Model 1, labeled, see simulation.

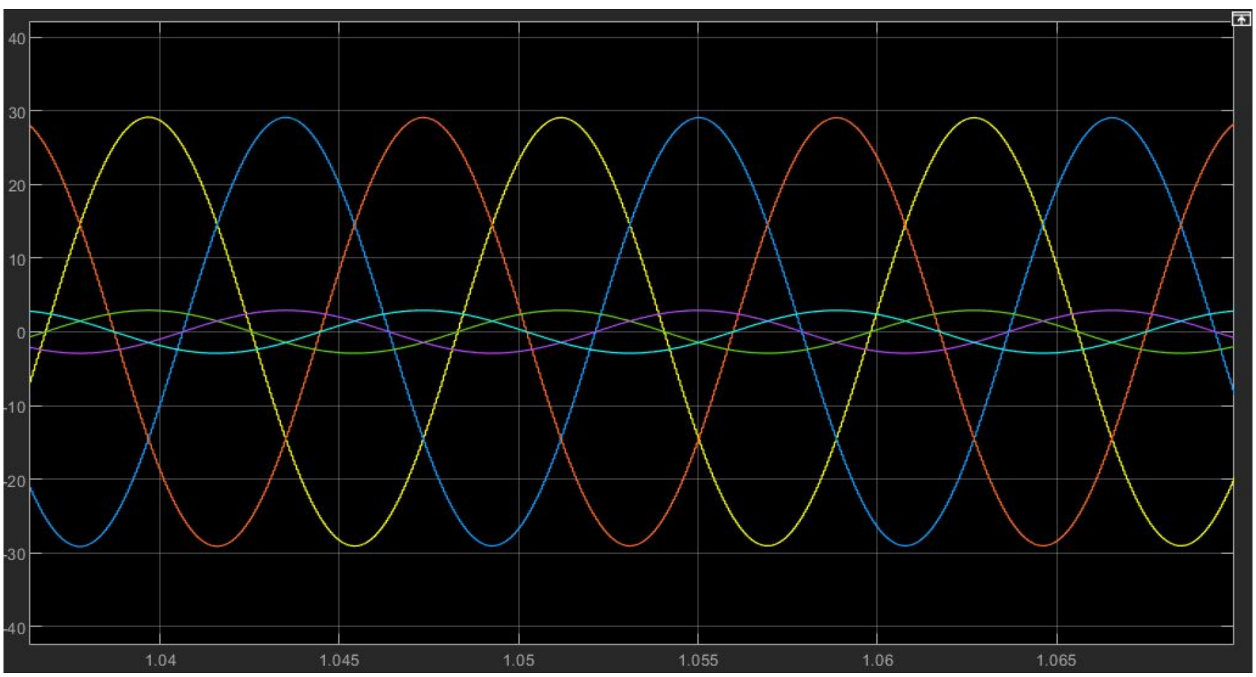


Figure 6: Model 1 waveform, see simulation.

3.0 Battery Bank Model 2

Model 2 with battery, see simulation.

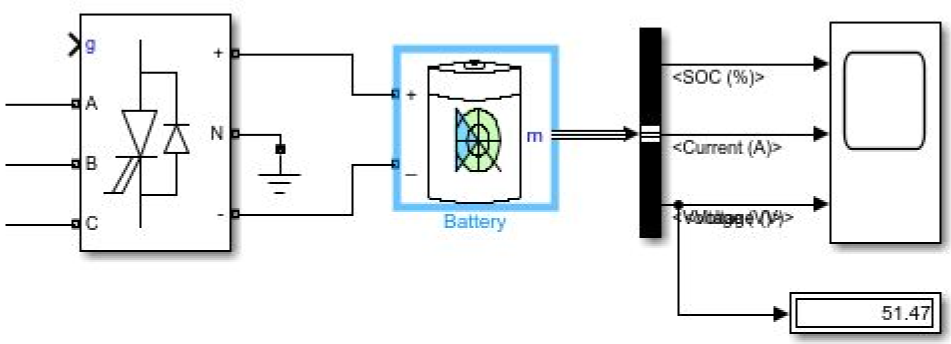


Figure 7: Model 2 with battery addition, charging a 48V battery, see simulation.

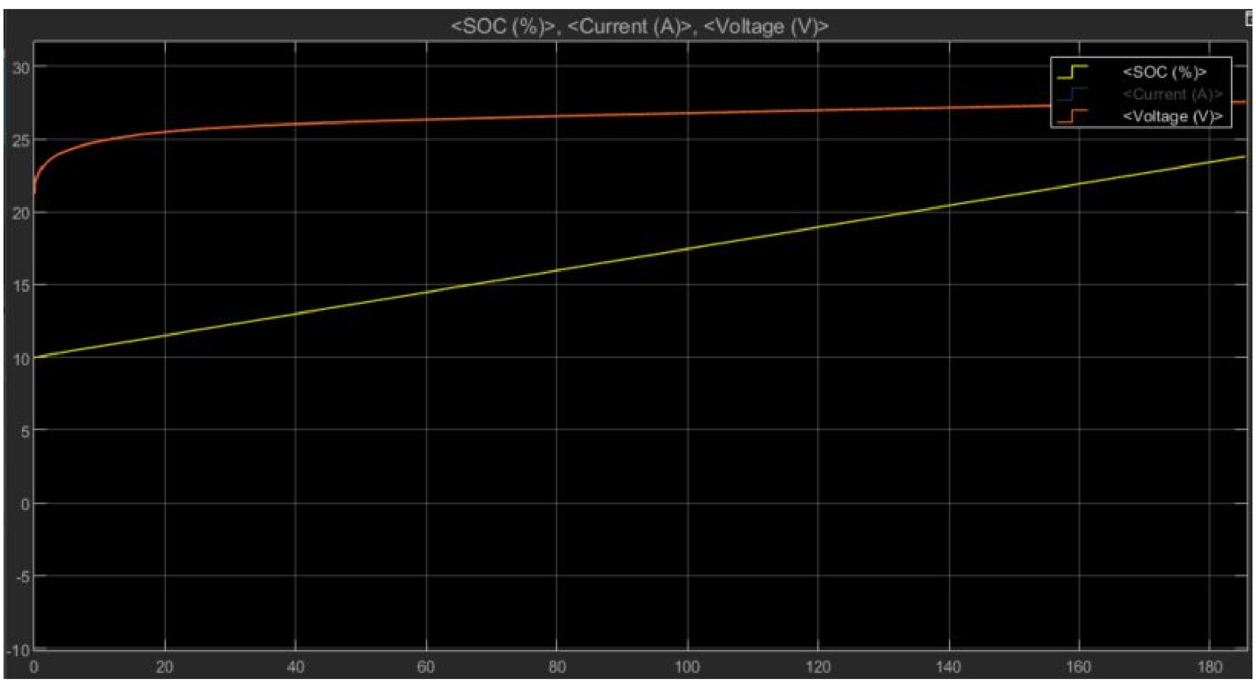


Figure 8: Model 2 waveforms of battery Voltage charging up and SOC rising, see simulation.

4.0 Conclusion

Mitchell worked on the formulas and report initially, and created resistive load model 1. Deep took over and modeled the battery bank model 2 while finishing up the report. We both tried modeling different examples for the resistive load at the beginning to get a working model.

We faced the issue of our simulation not working initially, so we switched back to the values found in the example video and changed them one by one to our selected turbine model numbers. This allowed us to isolate the issue with a function block and correct the error.

This lab gave us the knowledge of how to model the different parts of a wind turbine system in Matlab. We realized the formulas shown in class with a real turbine and its datasheet to simulate its operation.