Educational Wind Powered Charger

ECE 445 Project Proposal

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1 Introduction

1.1 Objective and Background

As more industrial companies turn to cleaner energy utilization, wind power has become one of the main power sources for energy supply. From an industry point of view, it would be a good idea to teach students how this technology is used in real-world applications. An exemplary application would be a bike-mounted wind electricity generator.

Lots of cyclists prefer to ride in wild areas, such as mountains, grasslands, and remote gravel tracks, where electricity is absent. A charging tool that can supply power to portable electronic devices would be beneficial. This product farms wind with a 3 blade rotor and convert the energy into electricity. When riding the bike, the coming wind would directly be converted into electricity, which ensures sustainable high wind speed for the power supply.

We would also implement a pitch angle adjustment technique that prevents strong winds from destructing the system. Although there are commercial products available, they are not operational when having a rest, not adjustable for wind speed, and expensive. This design intends to provide a relatively cheap, portable, self-support, ever-ready, and educational battery charger to customers.

1.2 High-Level Requirements

- **Reaction speed of pitch should be $<$ 1s.** We want to farm energy and protect our rotor as responsive as possible. As a result, the pitch adjustment must sense the changing wind speed quickly and modify its angle. On the other hand, we cannot make the reaction speed too fast. The sensor has a periodical measurement by itself, and a delay is needed to prevent the system from being too sensitive to unstable wind conditions.
- **Pitch angle should fall between $0°$ and $90°$ with at least three angle variations.** The pitch angle will respond to the wind speed to change its angle, the greater the speed, the greater the angle. To allow the wind turbine to harvest as much as possible and prevent destruction to the system. The pitch must be feathered when the wind becomes too strong.
- **The entire system's width must not exist 45 cm.** We do not want our wind turbine to be too large in diameter, which might disturb view of riders.

1.3 Visual Aid

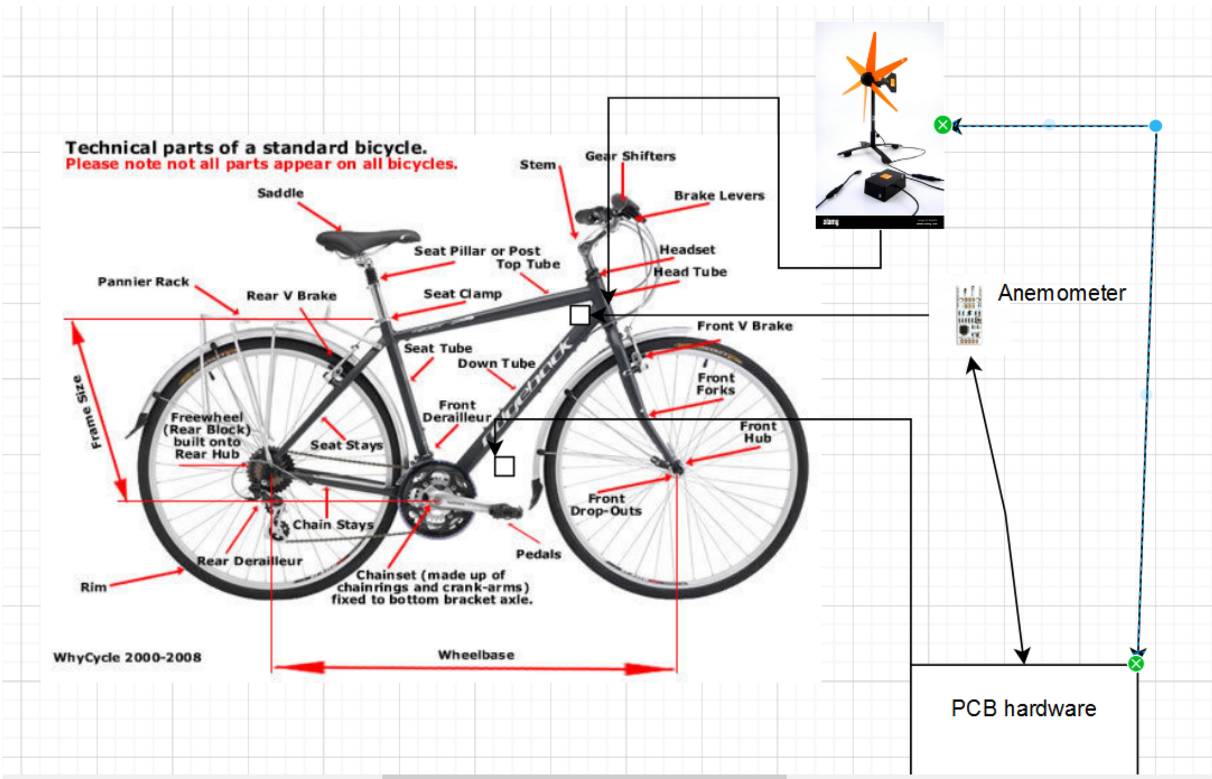

Figure 1: Visual Diagram for the System. Both sensor and turbine itself will be mounted on the head tube of the bike. All the PCB hardware will be mounted on the down tube. When you ride the bike, the wind pushes the blade on turbine and make electricity. Anenometer is going to communicate with hardware to instruct the turbine to change pitch

2 System Block Diagram

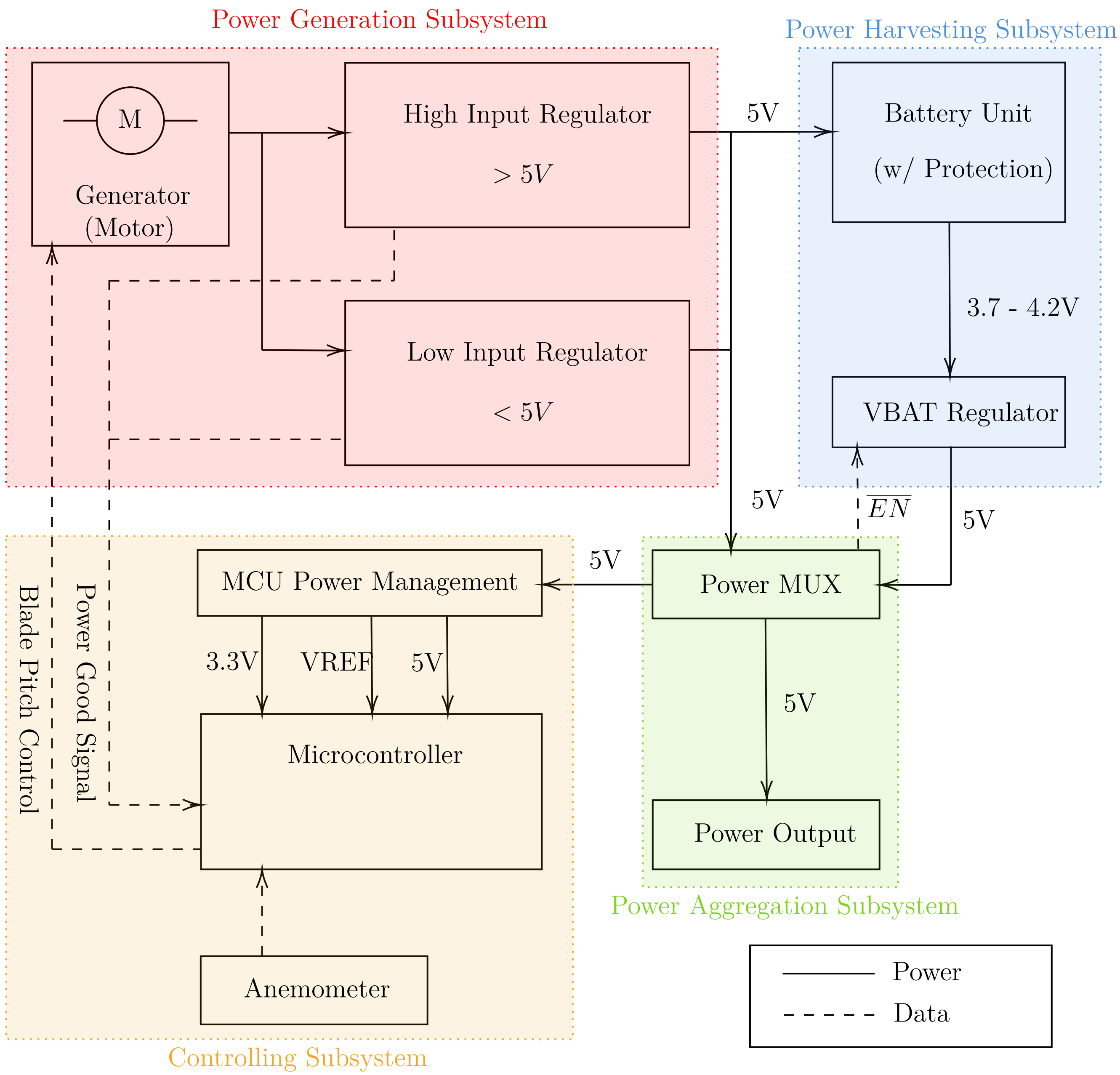

Figure 2: Block Diagram

2.1 Subsystems

2.1.1 Power Generation Subsystem

This subsystem holds the wind turbine, AC/DC diode bridges, buffers, and regulators. It generates energy from wind power and provides an unstable 5V output. The current capability of this 5V output cannot be relied on.

This unit also outputs a `Power Good` signal indicating that the input voltage is within operational range. This signal will be consumed by the microcontroller.

This unit accepts blade pitch control signals from the microcontroller and changes the angle of attack of the turbine blades accordingly. There are 3 servos in this system in total. Those servos serve to change the blades' pitch angle simultaneously. There will be at least 3 angles within [0,90] degree range based on specific wind speed.

Expectations of this subsystem: This system should provide a 5V output and a PG signal when there is enough wind power. When there is no wind power, there should be no PG signal, and no output is expected. The servo will turn smoothly based on the microcontroller's control signal simultaneously.

2.1.2 Power Harvesting System

This subsystem holds a battery and its *Maximum Power Point Tracking*(MPPT) charger. the MPPT charger will control the charging current of the battery in order to achieve the maximum power input. Such units are common on lots of renewable energies, such as solar panels and wind turbines. The VBAT regulator can also be disabled by signals from Power Aggregation Subsystem.

This subsystem has a 5V regulator output, which could be toggled on or off depending on the need. The regulator could supply up to 2A of current.

Expectations of this subsystem: This system should be able to charge from an unstable power supply and provide a stable 5V output when asked.

2.1.3 Power Aggregation System

This subsystem chooses a power supply from either the generators or the battery, and delivers it to the Controlling Subsystem and the output. It serves to detect whether the 5V output from the Power Generation Subsystem is reliable and toggles the battery output accordingly. The Power MUX in this subsystem could also disable the VBAT regulator in Power Harvesting Subsystem.

It provides stable, reliable 5V output to the power outlet and the Controlling Subsystem.

Expectations of this subsystem: This system should provide a stable 5V output from the best available source.

2.1.4 Controlling Subsystem

This subsystem holds the sensor (anemometer) and the microcontroller unit. The microcontroller will monitor the wind speed, decide the best angle of attack for the wind turbine, and send the control signals to the servo motors controlling the angles of the fan blade.

Expectations of this subsystem: This system should provide the servo in Power Generation Subsystem with the correct signals to change the angles of the blades.

2.2 Components

2.2.1 Generator

- The generator is a wind turbine, generating an unstable voltage up to 12V. Due to the large variation in power output, the generated voltage will be regulated by either of the two voltage regulators, both of which are designed for high efficiency.

- This generator also features a blade on which the pitch could be changed, so it could achieve an optimal point of operation that most effectively utilizes wind power.

- **Requirement 1**: Must supply enough power to charge a battery

- **Requirement 2**: Must include 12 +/-5% output voltage in its output range

2.2.2 High Input Regulator

- This regulator is only activated when the generated voltage is higher than 5V +/-5%. It produces a 5V +/-5% output when input power is adequate, and provides a PG (Power Good) signal when the output is OK.

- Current drafts uses TPS629210 as the main component.

- **Requirement**: Handle inputs that are greater than 5V, and generate a 5V output. The current output capability is not counted on.

2.2.3 Low Input Regulator

- This regulator is only activated when the generated voltage is lower than 5V +/-5%. It produces a 5V output when input power is adequate, and provides a PG (Power Good) signal when the output is OK.

- Current draft uses TPS63802 as the main component.

- **Requirement**: Handle inputs that are lower than 5V, and generate a 5V output. The currrent output capability is not counted on.

2.2.4 Battery Unit

- This unit is built with Maximum Power Point Tracking (MPPT) to draw and store the largest amount of power from the output of the wind turbine. It also serves as a stable power pool for the digital parts of the system, such as the micro controller.

- The battery also has a protection circuit, preventing overcharging and over-discharging. Its output voltage will be 3.7 to 4.2 volts, depending on the charge of the battery.

- **Requirement 1**: It is able to capture the maximum power point of the previous stages.
- **Requirement 2**: It will shut off charging process in the conditions of overcharging.

2.2.5 VBAT Regulator

- This regulator converts the battery voltage into a stable 5V for powering the USB output or the micro controller.
- **Requirement 1**: Converts battery voltage into 5V with around 2A of current output.
- **Requirement 2**: Could be turned off to achieve higher efficiency when the motor is generating enough energy

2.2.6 Power MUX

- This multiplexer chooses a power supply from the generator or the battery unit. When the generator is producing enough power, it switches off VBAT regulator.
- **Requirement**: The MUX provides stable 5V outputs to the power output outlet and the microcontroller units.

2.2.7 Servo

- There are 3 servos, each controls the pitch angle of 1 blade. They will simultaneously respond to the signal from microcontroller to turn the angle accordingly. It is mainly used to prevent destruction to blade from extreme wind.
- **Requirement 1**: The length of 2 servo should not exceed 2 cm
- **Requirement 2**: The weight of motor should not prevent blade from moving

2.2.8 Power Output

- Most portable electronic devices come with a way to be charged through a USB port, so the power output is expected to be a USB port.
- To prevent over-current, the USB port could be fitted with an e-Fuse that opens when the current is too large or there might be a shortage, and resets itself automatically after a period of time.
- **Requirement**: A sturdy USB port, providing charge to universal portable electronic devices.

2.2.9 MCU Power Management

- This unit takes 5V and steps it down to 3.3V for different parts of the microcontroller. It also provides a reference voltage for the analog-digital converters in the MCU.
- **Requirement 1**: Provides 5V and 3.3V to the microcontroller, as well as a stable voltage reference for ADC.

2.2.10 Microcontroller

- The microcontroller unit measures wind strength by taking input from an anemometer, and it adjusts the angles of the blade to certain levels, achieving max utilization of wind power.
- **Requirement 1**: Drains little power.
- **Requirement 2**: Powerful enough to carry out calculations and deliver servo signals.

2.3 Risk Analysis

The greatest challenge lies in the MPPT control technique in Power Harvesting Subsystem. It is hard to find a charge controller on the market that is suitable for wind power generations. Most MPPT ICs on the market are designed for solar power, which varies slowly due to the amount of sunlight. However, wind strength can vary abruptly, and by changing the angles of the blade, the output voltage and current capability of the turbine change a lot. Our MPPT algorithm has to take that into account.

At the current stage, we had two solutions: One is to adapt a solar MPPT IC. When there is an abrupt change in wind strength or the blade angle changes, we reset the IC to make it forget its previous state, so the IC will start looking for the optimal point again. The second solution was to implement our MPPT algorithm on the microcontroller, with a combination of stochastic gradient descent and data from the anemometer. Either method came with some difficulty, and we would call it a success if we could harvest around 75% power compared to the theoretical result.

With a properly working MPPT, we would be able to harvest greater energy. This increased efficiency allows us to pick pitch angles with fewer constraints.

3 Ethics

Following the guidelines from the IEEE Code of Ethics, we are willing to develop this project to hold paramount the safety, health and welfare of the public(IEEE (Institute of Electrical and Electronics Engineers) Code of Ethics, 2015). Therefore, we will make sure that the mechanism is save to attach to a bicycle, to avoid any possible accidents due to a piece of our project falling off or distracting the rider.

To manage this, we will do lots of testing on different weather conditions and with the needed precautions to protect ourselves form injury, to make sure that we do not manufacture a dangerous object and make sure it is functional.

4 Safety

We are currently planning to mount the blade and servos in the front of the bike. As a result, there is a safety issue if the rider's hand somehow touched the rotating blade, which could cause damage to both rider and the rotor itself. As a result, we are planning to make the blade as circular as possible to avoid any sharp edges on the blade. Plus, we would like to make the rotor be a certain distance away from the head tube. The rotor should be located 10 cm in the front of the head tube. Also, considering the possibility that the rotating blade might disturb the view of the rider, we will make the mounting position as low as possible on the head tube.

After carefully checking federal and state regulations, industry standards, and campus policy, we need to follow safety rules in the lab. As concerns for safety for working in the lab, we promise not to allow any group member to work alone in the lab session. Instead, there should be at least another member or a TA working together. Plus, we will not bring any food into the lab and always clean the table to keep the working station clean. This behavior could prevent any accidental touching of electronic devices hidden under the messy table(ECE 445 p.3). The biggest safety concern for us is accidentally touching high voltage circuits without protection and misconduct during soldering. But if we are careful with our implementation, we should be able to do our job successfully.

5 Reference

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