ElecTrek
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EE 41430
Senior Design Proposal

I. Introduction

Throughout the course of this project, we expect to learn about many aspects of the design process. The initial step of identifying a problem demonstrates why the design project is necessary. Our team has a specific customer who requested a group of engineering students to find a solution for his problem. After meeting with our customer, we have a good understanding of his project expectations and what problem we will be solving.

II. Problem Description

Our senior design project involves working closely with Outpost Sports, a sports equipment and cycling facility in South Bend. The store owner, J.V. Peacock, reached out to the College of Engineering for help with this project. He wants to capture, store, and use energy created during cycling practices at his store. His facility offers cycling training classes for elite cyclists who practice in the winter. His training facility can accommodate eight cyclists at each class using a system called CompuTrainer by RacerMate. This system allows cyclists to attach their own bike into a rack and a variable-resistance device. Software is used to control the resistance felt by the rider. The CompuTrainer system also includes videos of international races to show the riders where they are in the course. See Figure 1 for the CompuTrainer setup.

Figure 1. The CompuTrainer system.

The CompuTrainer software calculates various parameters about the ride, including the wattage generated during each ride. Advanced cyclists measure their workouts based on the average number of watts they generate during a workout. The average power generated during these half-hour classes is 250 watts per cyclist. Mr. Peacock wants to use the power generated by the cyclists to do useful work. Currently, the power generated during the classes is discarded as heat. Capturing the energy generated during cycling practices would have many benefits for Outpost Sports. The collected energy could power other equipment, such as fans, lights, or an iPod. The number or type of devices that we are able to power is contingent on how much power we can actually generate.

The primary goal of the project is to convert the rotational energy of the tire into electricity. The CompuTrainer controls the resistance seen by the rider. The bike and CompuTrainer system are anchored together by a frame that holds the axle of the back wheel in place. See Figure 2 for the interface between the bike wheel and the CompuTrainer variable-resistance system.

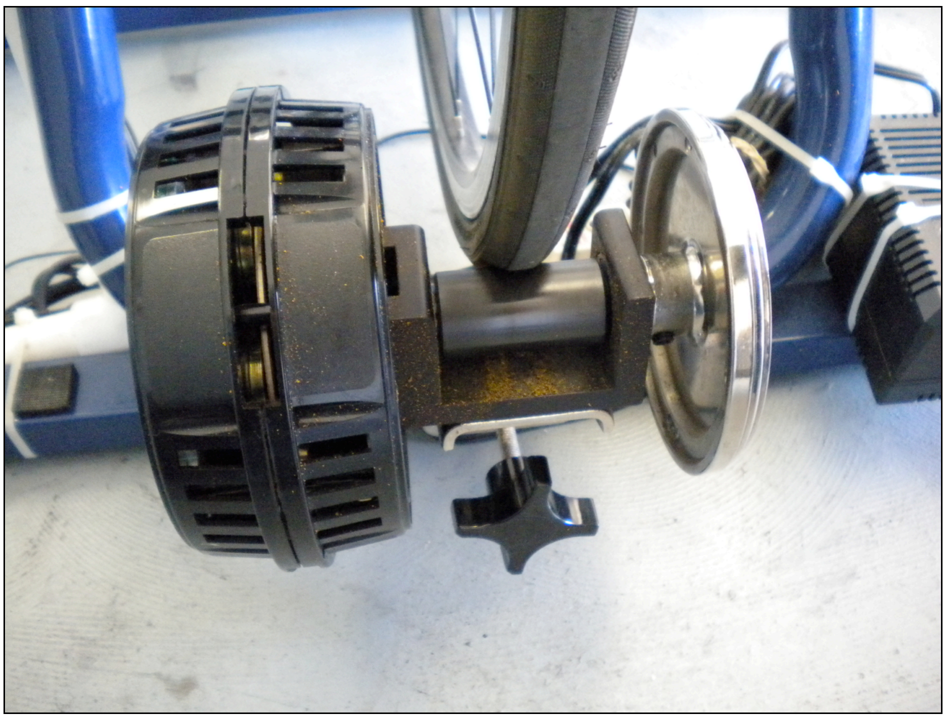

Figure 2. The interface between the tire and the CompuTrainer system.

Another problem associated with this project is ensuring that the rider encounters a variable resistance throughout the race. The main goal of indoor cycling at Outpost Sports is for the rider to experience a realistic race course, and the CompuTrainer system provides this simulation. It is crucial that our design does not detract from the simulation. Our system will add some resistance for the rider, which may impact the calculations made by the CompuTrainer software. This is a consideration that will need to be considered, but it is an unavoidable consequence. An unacceptable effect is one that causes a cyclist to avoid using Outpost Sports for off-season training after implementation of our energy-storage project.

III. Proposed Solution

The design will use a generator to convert the mechanical energy of the braking system to electrical energy. This electrical energy will then be stored in a battery as chemical energy for later use. A major goal is to make the system as non-invasive as possible to prevent voiding the warranty on the CompuTrainer system and altering any of the commercial software. Designing a non-invasive system will also allow for easy attachment and detachment of our system to the bike. The design could then be duplicated for each of the eight bike stations in the facility.

To accomplish this, we will have the rotating shaft of the generator in direct contact with the bike wheel. We will use a permanent magnet DC generator because it operates at a speed compatible with the bike. There will be no additional gears between the generator and the bike wheels. The generator will output a DC voltage. The system requires a battery that can handle many deep cycles and still have a long lifetime. Because of this, we will use a lead-acid deep cycle battery. Current flowing into the battery will be regulated to avoid damaging the battery.

Once the battery is charged, the generator needs to be disconnected. We will use a microcontroller to monitor the voltage level of the battery to determine its charge level. This information will be displayed on an LCD screen controlled by the microcontroller. The screen will also display the instantaneous power, peak power, average power, and total energy generated. We will measure each of these parameters with sensors at the generator and the battery.

IV. Demonstrated Features

Conversion of mechanical energy to electrical energy
The project will generate electricity from the 30-minute training session on the CompuTrainer system. It will do this by storing the energy in a battery. Mechanical energy from the rotation of the bike wheel will be converted to electrical energy at the output of the generator, then to chemical energy in the battery. This chemical energy will then be converted back to electrical energy when the battery is discharged.

Rider's training regimen will not be disturbed
The addition of our system will increase resistance at the wheel but will still allow for the variable resistance needed in training conditions. Our system will not impact the CompuTrainer software. Instead, we will calculate a resistance factor caused by the generator. We will provide the user with this factor to account for the additional resistance.

LCD displaying statistics of power and energy generation and battery status
An LCD screen will inform the user of how much energy has been generated, how much is being generated at that moment, and what the peak power is in the training session. It will also display the battery's charge level. This screen will be controlled by the microcontroller.

Automatic disconnect from the battery
When the battery is fully charged, the microcontroller will automatically disconnect it from the generator to avoid overcharging.

V. Available Technologies

Our design requires several key technologies: a generator, a battery, and a microcontroller. Decisions on these components will impact the design and capabilities of the entire project. Additionally, the system will use voltage sensors and an LCD to provide information about power generation and battery status to the user. These components will all need to be available and affordable enough to fit within our $500 budget.

The choice of generator is impacted by two important considerations. First, we are limited by the power coming from the cyclist. Bicycles operate around 100 rpm and, according to Mr. Peacock, the cyclists are generating an average of 250 watts per person, peaking around 400 watts. Taking into account the difference between wheel size and the shaft of the generator, our system requires a generator that can operate in the range of about 2,000 rpm and output several hundred watts of power. The second consideration is the type of current and voltage required by our system. We will be storing generated power in a battery, so we require direct current. Either automotive alternators or permanent magnet DC generators could be used. Automotive alternators, however, generally require rotations closer to 10,000 rpm. DC generators of the size and speed we need are available and fit well within our budget.

Our system will be storing power in rechargeable batteries with two important requirements. Our generator can produce several amps while in operation, so our batteries must handle a large charging current. Additionally, we can expect the batteries to be deep-cycled, meaning they will be almost fully discharged before the next charging. Lithium-ion batteries offer high energy density without the “memory effect” that plagues some other rechargeable batteries. However, these batteries are more expensive than other battery types, and multiple batteries would have to be wired in parallel to fully capture our generated power. Another option is lead-acid batteries, which come in several different varieties. Lead-acid deep-cycle batteries are designed specifically to be cycled frequently, unlike standard automotive batteries. These batteries are commonly used in wind and solar generation systems and offer charging currents of several amps.

Finally, the microcontroller will need to read current and voltage sensors, disconnect the battery, and output to an LCD.

VI. Engineering Content

We must address several functional blocks and their interconnections (see Figure 3). The first functional block is the bike wheel and DC generator interface. This subsystem converts the mechanical power generated by the bike into DC electrical current. The interfacing issue arises from the friction between the bike wheel and the generator shaft, which increases the resistance experienced by the rider. The engineering challenge will be to minimize the resistance caused by the generator setup while maximizing energy conversion.

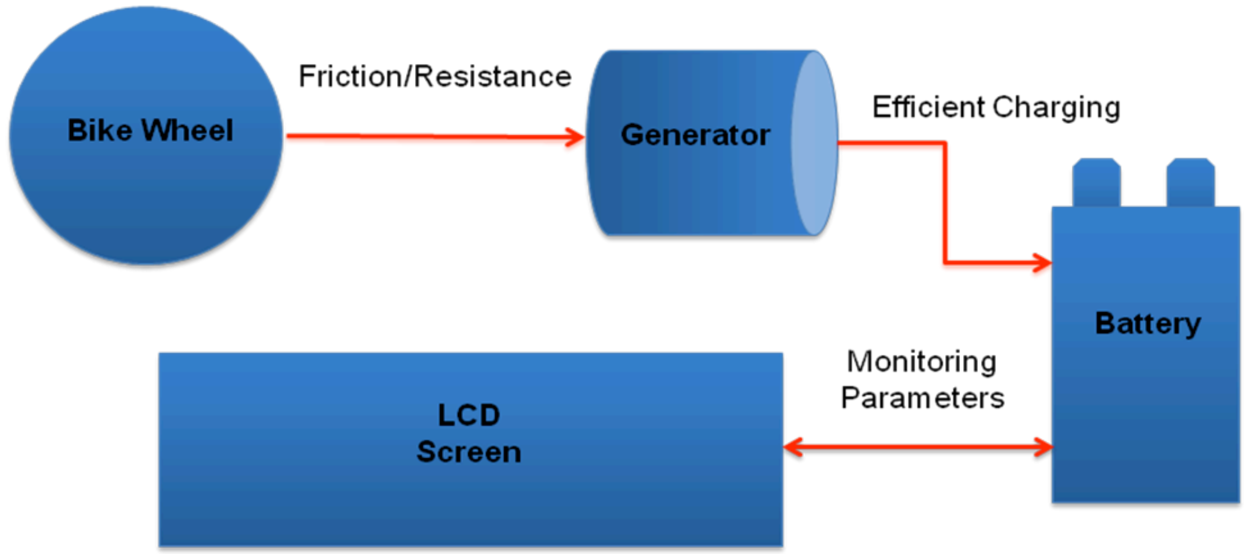

Figure 3. Functional block diagram of the energy capture system.

The functional block of the battery presents many engineering challenges. First, there is the issue of regulating the current coming into the battery from the generator. This is determined by determined by the pedaling speed of the rider (i.e. the rpm of the bike wheel). The required battery properties also must be considered. These include the ability to handle deep-cycling, high energy density to operate efficiently, ability to handle intermittent charging (due to variable generator output), and the voltage at which the battery charges. From these requirements, the type of battery must be determined. Our current choice is lead acid batteries used for solar power applications since these are designed for intensive deep cycling.

Issues related to the microcontroller in our design include how to monitor various data, such as current and power output of the generator, battery charging voltage, and level of battery charge. It is important to monitor these values so we can display them in a user-friendly format to an LCD.

The overall engineering considerations fall under two main categories: power conversion and the impact of increased resistance. We have already discussed the relevant power conversion issues. The second concern is how the added resistance of our generator will affect the performance of the CompuTrainer system. The CompuTrainer device generates variable mechanical resistance to affect the difficulty of the rider's pedaling experience. Adding a generator to interface with the wheel will increase the overall resistance. We will calculate the added resistance of the generator and derive an algorithm for the user to account for the overall resistance.

VII. Conclusions

The main goal of our project is to enhance the CompuTrainer system by capturing the power generated during the cycling training sessions. Our project will provide an additional source of power for Outpost Sports and will produce useful energy from the motion of the cyclists' tires. Our system will interface with the bike wheel and provide energy-storage benefits. One of our main project requirements is to avoid interfering with the rider's training. The cyclists rely on Mr. Peacock's facility to have the most realistic cycling experience during cold weather. To accomplish this project, we will research affordable technologies, investigate appropriate interfaces between components, design a circuit board for monitoring and control, and coordinate all of the subsystems into an efficient energy capture and storage system.