Power Pedal: Harvesting Electrical Energy From Biking

Nouran Youssef, Obaid Ajoughlal, Christopher Neill, Mateja Markovic
Professor Deborah A. Fixel Ph.D.
Professor J. Harry Blaise Ph.D.
Trinity College, 300 Summit St, Hartford, CT 06106 USA

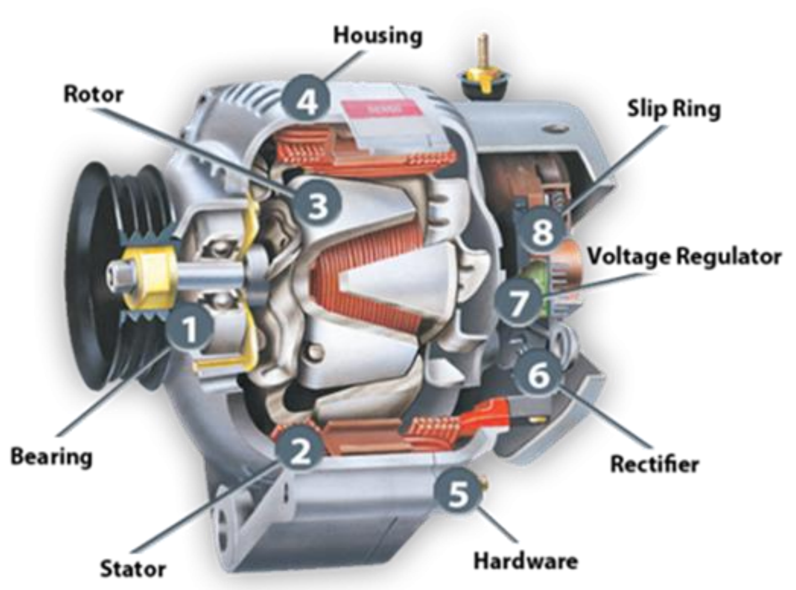
Background

The idea of using a bike mounted on a trainer for household energy needs reflects the versatility of the concept. This approach doesn't only encourage physical activity and a healthier lifestyle but also transforms the act of cycling into a multi-purpose activity, promoting both personal well-being and sustainable energy generation. Harnessing human-generated power through the act of pedaling aligns with the global shift toward eco-friendly energy solutions, addressing the pressing need for sustainable practices in our daily lives. Using this energy in households, or even on a bigger scale at a local gym will help promote these needs among the common people and has the potential to put some pressure off of our energy grid.

The idea of using alternators on bicycles to convert mechanical energy into electrical power draws inspiration from the principles of electromagnetic induction. As the cyclist pedals, the rotational motion of the bike's wheel can be transformed into electrical energy through the alternator. This energy can then be stored or used directly to power electronic devices, creating a symbiotic relationship between physical activity and electricity generation.

Design Requirements

Design constraints are important to consider during the engineering process. Effectively addressing constraints is crucial for ensuring success. Many of the constraints encountered were either budgetary or related to the specifications of the alternator. Our team operated on a $400.00 budget, which was spread between many of the acquired components. The bike itself cost $50.00, a free bike stand, an alternator and belt for $163.00, a 400W inverter for $38.00, a 12V SLA battery for $35, and a variety of fasteners for $27.00, totaling $301.00 Another major design requirement was mounting the alternator in a way that it would not impede the ergonomic usability of the bike. The alternator had to be placed in a location that would not impact user comfort or the ability of the end user to pedal.



Incorporating IEEE standards into this Capstone Project is important to ensure the safety, reliability, and feasibility of Power Pedal. Since our project relies heavily on energy conversion, the most important standard to adhere to would be IEEE 1547-2018. In fact, it outlines the standard for interconnecting circuit components with electric power systems, which will ensure that the Power Pedal can safely interface with external power systems. In addition, controlling the harmonics in this electrical power system requires respecting the IEEE 519-2022 standard. It will ensure that the generator's output voltage and current meet acceptable levels and do not cause any interferences with the rest of the electrical equipment. Another crucial factor in the success of this project is making sure that all components are protected to guarantee proper functioning. That is where the IEEE 1100-2005 and NFPA 79 standards provide guidance on powering and grounding electronic equipment, which protects sensitive components from electrical noise. ASME B.18.2.1 is a standard that governs the dimensions of hex bolts used in our mounting system to ensure uniformity and interchangeability across various industrial applications. 4/0 AWG wire was used to transmit energy between the alternator output and the 12V battery. The inverter we selected adheres to NFPA 79 and provides two standard North American electrical outlets as well as two USB 3.1 ports. The outlets and USB ports are used to power any appropriate devices that the end user desires.

Figures 3&4, details the mounting system for the alternator on the bike frame

REFERENCES

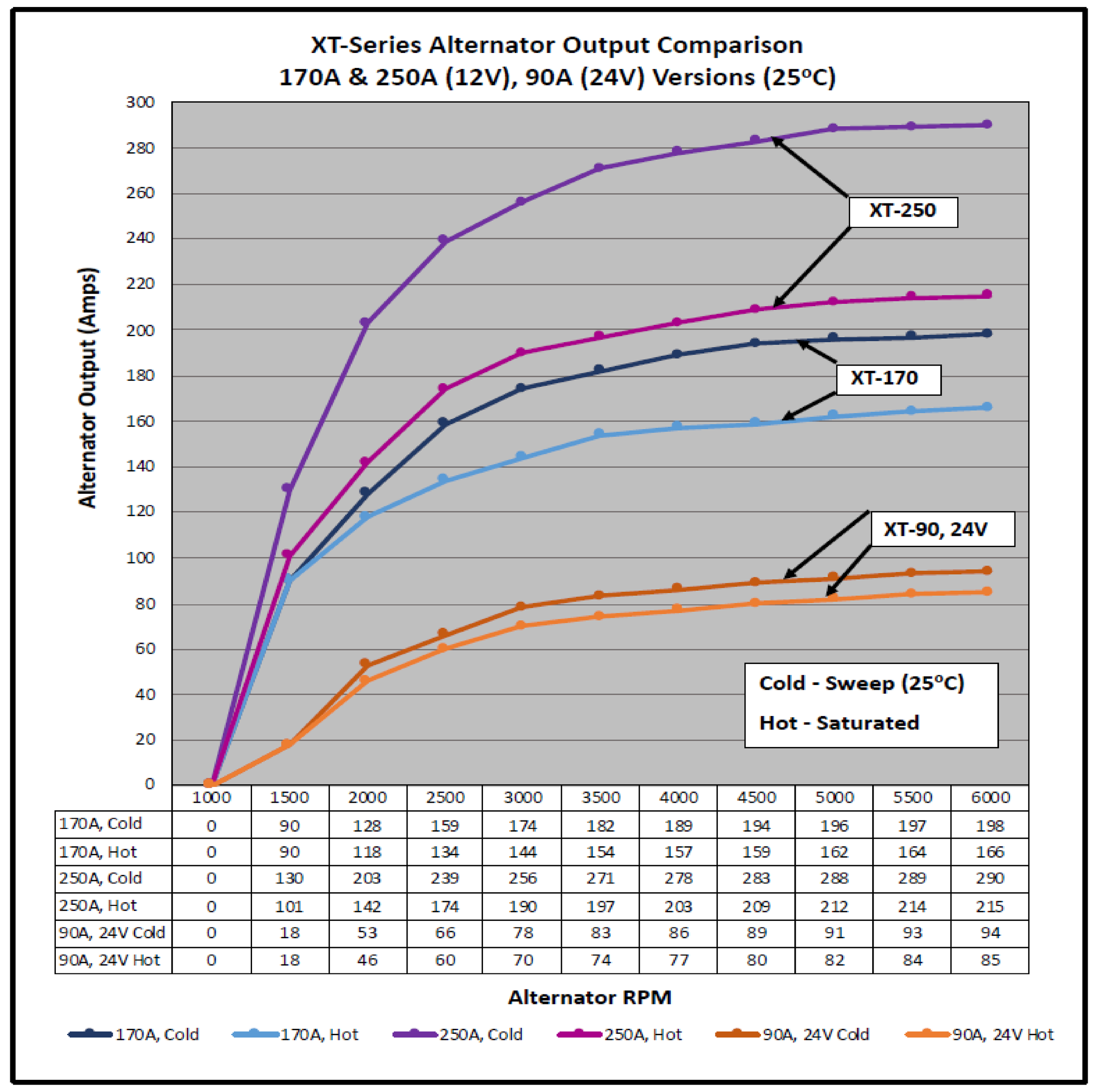
1. "XT-Series Alternators Designed for Recreational Applications." Balmar.Net. Accessed 9 Dec. 2023.
2. Temple University Press. (n.d.) One Less Car

Design Alternatives

- ***Street bike vs Stationary bike***
  - We have decided to use street bike for our project instead of Stationary bike for multiple factors.
    - **Mobility and Versatility**: Generating Power while moving makes it practical for on the go charging while outdoor.
    - **Sustainability:** Generating electricity from street bikes produces minimal to no carbon emission which can help reduce carbon footprint.
    - **Accessibility:** Street bikes are cheaper and accessible for everyone unlike stationary bikes that are more expensive and could require user to obtain gym memberships.
    - **Human power with no external source:** Unlike stationary bikes that may require electricity for additional features, street bikes would operate only on human power.
    - **Community awareness:** Could help start a sustainability mission to engage people in energy renewal discussion and motivates them to contribute to environmental conversion.
- ***AC Motor, DC motor, Alternator***
  - We have decided to use Alternator to power our electrical system after the benefits and drawbacks analysis.
    - **DC Motor**: Has multiple advantages as efficiency has multiple advantages such as efficiency, simplicity, control, and smaller size and weight compared to other motors. However, it also has some drawbacks, including direct proportionality between its voltage and RPM, startup resistance, wear and tear, limited power output, and complexity of conversion.
    - **AC Motor:** Some of its advantages include the constant of voltage, efficiency, no required start up resistance and no commutator. However, it also has some drawbacks like the absence of the voltage rectifier, would need an extra circuitry for voltage regulation and higher cost.
    - **Alternator:** Some of the appealing features of the alternator includes its high efficiency, constant voltage output, variable RPM Operations, availability and it's built in rectifier which allows for a more simplistic circuit. The only drawback would be size and weight along with cost, but it was in range of our budget.

Final Design and Implementation

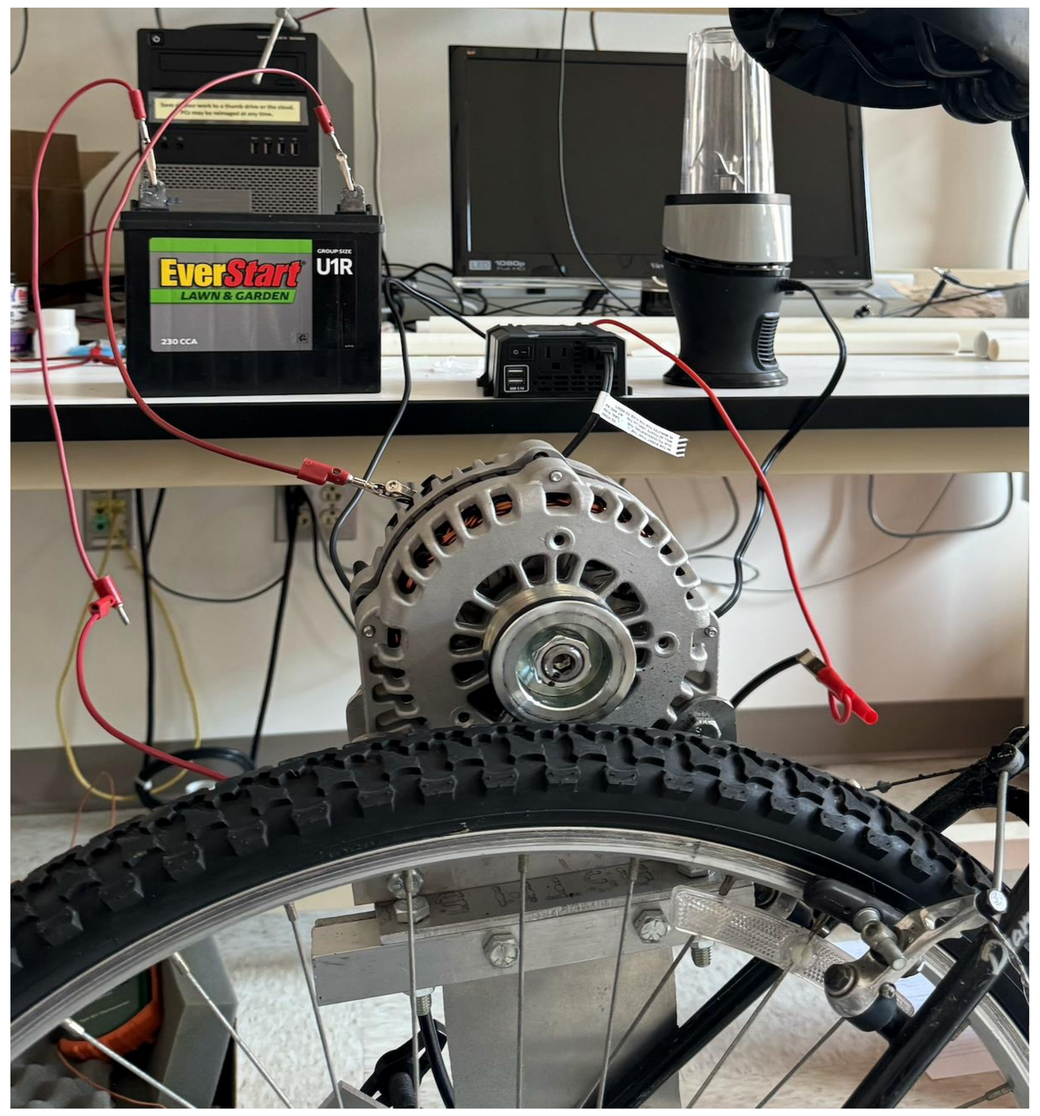
The mounting system for the alternator was designed and fabricated to maximize the gear ratio between the bike's rear wheel and the alternator pulley. By mounting the alternator directly to the wheel, we were able to achieve a gear ratio of 10.76:1, meaning a pedaling speed that would translate to a road speed of 6 mph would translate to an alternator speed of 1500rpm, assuming there is no slip. This RPM correlates to 130A.



	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000
170A, Cold	0	90	128	159	174	182	189	194	196	197	198
170A, Hot	0	90	118	134	144	154	157	159	162	164	166
250A, Cold	0	130	203	239	256	271	278	283	288	289	290
250A, Hot	0	101	142	174	190	197	203	209	212	214	215
90A, 24V Cold	0	18	53	66	78	83	86	89	91	93	94
90A, 24V Hot	0	18	46	60	70	74	77	80	82	84	85

Figure 1: Power curve for XT-250 series alternator

The final design for the alternator mounting system was fabricated in the machine shop from aluminum stock and fastened to the alternator and held in place using ASME B.18.2.1 standard hex bolts.



Design Evaluation

Our final design successfully powered a blender. We were able to power the 400W inverter easily. We were initially unable to measure the power output of our system due to the amount of current the system was outputting. The multimeters at our disposal are only able to measure 10-20A for brief periods of time. Since our system was generating much more current than this, we designed a parallel circuit to measure the current. The circuit was designed in parallel with the 4/0 gage AWG charging wire, and the current across the parallel circuit would be proportional to total current being output from the system.

$$I = i\left(\frac{R}{R_{int}} + 1\right) \quad \text{Equation 1}$$

I: Current passing through the 4/0 gage AWG charging cable
i: Current passing through the parallel circuit
R: 2kΩ resistor in the parallel circuit
R_{int}: internal resistance of the 4/0 gage AWG cable, equal to 0.89956 mΩ

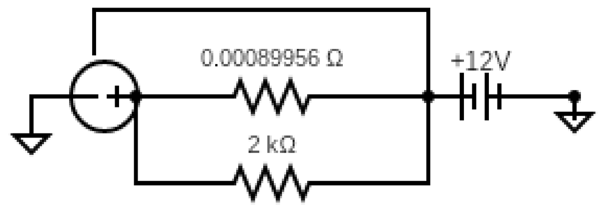


Figure 2: Circuit Diagram for parallel circuit to measure output DC source represents alternator, wire going into the top represents the excitation charge

At a sustainable pedaling speed, 24.108 μA were measured to be passing through the parallel circuit, and by using equation 1, we determined 53.6 A at 12.55V were passing through the main alternator cable. Using Watt's law, we determined 672.68W of power were being captured by our system. For comparison, an iPhone 15 requires 20W of power to charge in about 30 minutes, a household blender requires 250-500W, and a wall outlet is capable of outputting 1800-2400W of power.

CONCLUSIONS

Our system was able to effectively capture a significant amount of power. Future iterations of the project should focus on reducing slip between the rear wheel of the tire and the alternator. Since we were able to produce only 53.6 A compared to a maximum 130A at biking speed, we can determine there is a significant amount of slip between the rear tire and the alternator assembly. This could be eliminated by increasing the contact patch between the alternator and tire to increase friction. This could be done by extending the alternator pulley, that spans the entire width of the rear tire to increase friction. In summation, we were able to successfully capture a significant amount of energy with our system, meeting our design goal of powering small household appliances.

ACKNOWLEDGMENTS

- Trinity College Engineering Department
- J. Harry Blaise
- Dr. Deborah Fixel
- Dr. Lin Cheng
- Andrew Musulin
- Travelers