University of Victoria
Department of Electrical Engineering & Computer Science
ENGR 446 – Pro
Project Background
Fall Term 2022

DC Motor Speed Control for Bicycle to E-bicycle Conversion Retrofit

October 21, 2022

Branden Voss
V00913539
Electrical Engineering

Table of Contents

Background

With the recent integration of e-bikes in modern transportation, many opportunities within the scope of electronics technologies for cycling have emerged. Purchasing a new e-bike to replace your old conventional bicycle can be costly and inconvenient therefore, a viable alternative is to retrofit your old bike with the necessary peripherals to convert it into an electronic bicycle [1].

Currently, the best electric bike conversion kits allow for the addition of a motor to an existing bike simply and relatively cheaply compared to the price of buying an entirely new electric bike. There is an increasing number of e-bike conversion kits becoming available in the market which offer more sophisticated and easier to install hardware thus, making for a practical alternative to purchasing a new purpose-built e-bike. The retrofit would include a DC motor and it also needs to include the apparatus to control speed output of this motor. This usually takes the form of a bar-mounted display which can be controlled by the user to regulate the electric motors output in real time. The complete system would also include sensors to detect how fast the vehicle is travelling provide feedback to the rider [1].

The intent of this topic and the subject of subsequent reports is to examine methods of DC motor speed control for the e-bike conversion kit. When it comes to the success of this product safety is at the forefront of the discussion and thus, it is highly important to consider appropriate methods for regulating speed. Furthermore, the user should have control over the speed in a reliable and responsive manner.

First, this report will elaborate on the Flux Control method for dc motor speed regulation. This concept aims to reduce the magnetic flux between the rotor and stator since speed is inversely proportional to flux [2].

The second method of speed regulation is the Voltage Regulation method. The idea behind this concept is to provide a voltage supply to the motor’s shunt field which can be varied [2].

Lastly, the Potential Solutions section will cover the Armature Resistance Control method. This style of speed control relies on a constant voltage and armature resistance so that the motor speed can then be proportional to the armature current [2].

Problem

The objective of this work is to analyze safe, reliable and responsive methods of speed control for use in electronic bike conversion systems. There are three main methods to achieve speed regulation in DC motors. The method selected for implementation should be cost effective, lightweight and easily integrated with an existing bicycle frame. Furthermore, the method should allow for high performance operation that does not compromise the safety or reliability of the system.

Purpose

The final report on this topic will be necessary to assess the results and findings from research conducted on DC motor speed control. It is the intention of the final report to conclude the discussion and present a recommendation for the most appropriate speed control concept for this particular application.

Aims

This report has introduced the engineering problem at hand and will further explain the objectives of this problem. Furthermore, it allows for demonstration of a detailed understanding for the addressed issue and how potential solution will be assessed.

Limitations

The main limitation of this report is that the initial assessment criteria has not yet been given a metric to effectively compare potential solutions and is strictly limited to the analysis of DC motor speed control. It will not discuss information regarding any other components of the e-bike conversion kit. This report is further limited to a conceptual review of the engineering problem and potential solutions. No physical form of testing or product will be realized. The analysis conducted on the potential solution will be solely focused on findings from research and not on actual accounts of testing.

Potential Solutions

The subsequent section of this report will evaluate three potential methods of DC motor speed control on a conceptual level. The potential solutions presented are the Flux Control method, the Voltage Regulation method, and the Armature Resistance Control method.

Solution 1 – Flux Control

The Flux Control method involves a variable resistor is connected in series with the motors field windings. This method will increase series resistance in the windings to effectively reduce flux to increase the motor speed. The figure below shows the flux control configuration [3].

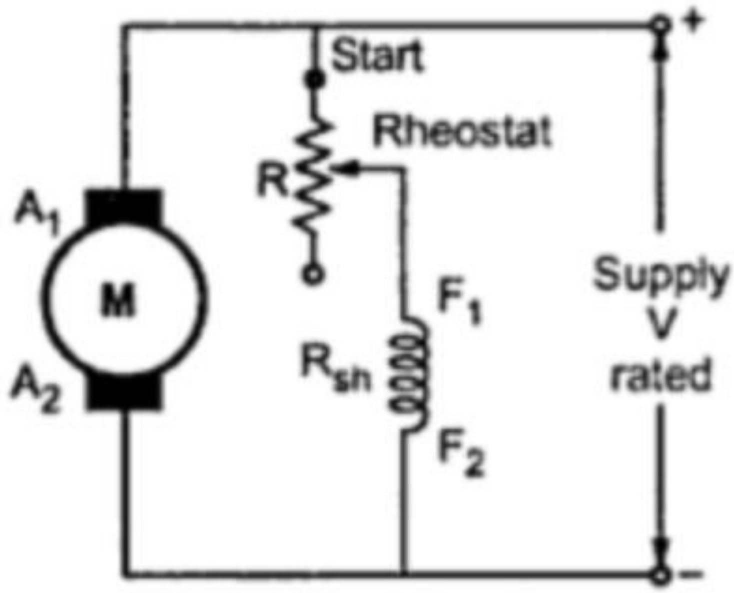

Figure 1: Flux Control Method [3]

Advantages [3]:

1. Provides smooth and easy control
2. Control above rated speed is possible
3. Economical and efficient
4. Small field current constitutes small variable resistor

Disadvantages [3]:

1. Speed control below normal rated speed is not possible
2. Motor operation is unstable at speeds much higher than normal rated speed

Solution 2 – Voltage Regulation

Next, the Voltage Regulation method, which is typically used in DC shunt motors, provides a varied voltage supplied to the armature as a means to regulate the moor output. This setup can be observed in the following figure [4].

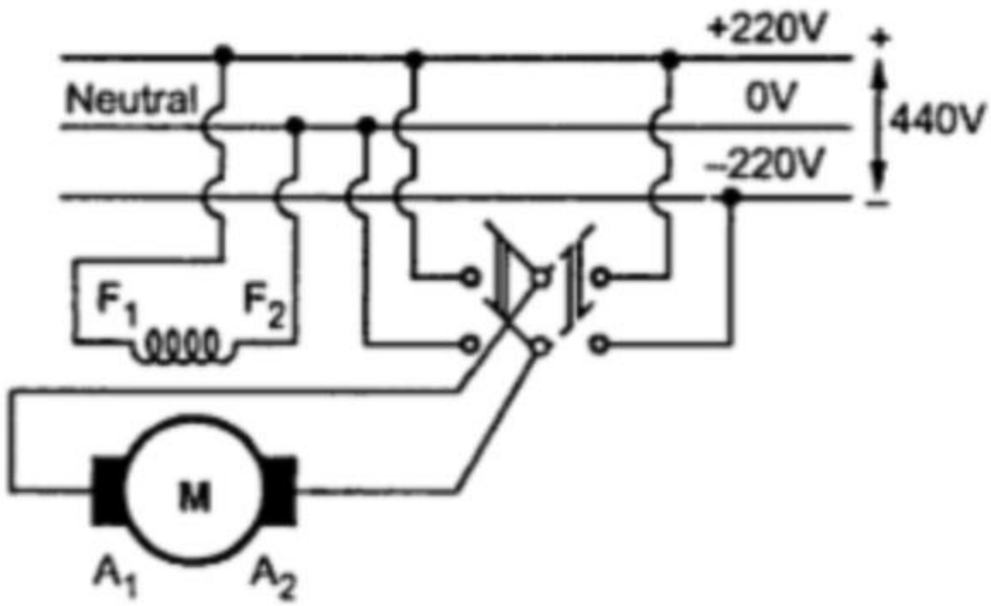

Figure 2: Voltage Regulation Method [4]

Advantages [4]:

1. Wide range of speed control
2. Allows for speed control in both directions
3. Can provide uniform acceleration

Disadvantages [4]:

1. Expensive cost of equipment
2. Low overall efficiency

Solution 3 – Armature Resistance

Armature Resistance Control Method: The speed of the motor is directly related to the back EMF. If the supply voltage and armature resistance are kept constant, the speed of the motor is proportional to the armature current [5].

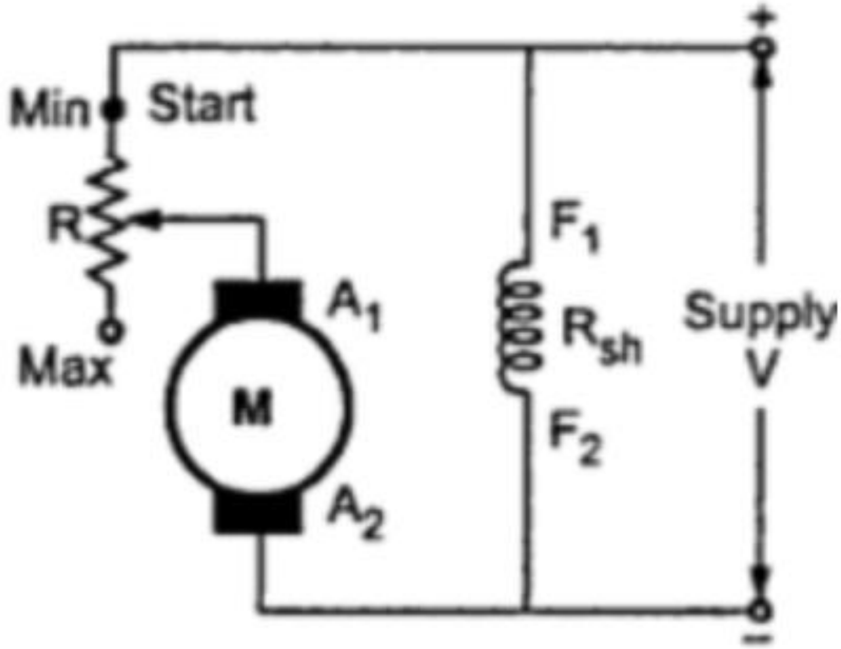

Figure 3: Armature Resistance Method [5]

Advantages [5]:

1. Easy and smooth speed control below normal rated speed

Disadvantages [5]:

1. Large power losses
2. Requires large variable resistor
3. Speed above the rated speed is not possible
4. Expensive and inefficient
5. Needs heat sinks which increases cost

Initial Assessment

The initial assessment of the previously discussed potential solutions is the topic of the following section. This section is further divided into subsections for ease of understanding and readability as it identifies key criteria in the initial assessment of speed control methods.

Safety

Safety criteria for the potential solutions will incorporate factors such as smoothness and responsiveness of the speed control method through a useful range of speed. A method with such characteristics is expected to provide reliable control in real time. Both options 1 and 3 where previously noted to have this advantage over option 2. However, it should be recognized that option 1 the Flux Control method experiences unstable operation at speeds much higher than the normal rated speed. This could potentially pose as a risk to users and will require further research and analysis. Much of the required information on this can be obtained through datasheet information and graphs related to these characteristics.

Performance

The speed regulation concepts will further be evaluated on their performance. The performance measure will account for efficiency, range, and acceleration. This criterion will also include the size and weight of the hardware required in order to assess how intrusive implementing such a system would be on a bicycle frame. Each potential solution offers some performance advantages and will need to be further assessed based on the intended application. It will likely be useful to evaluate the torque and acceleration of such systems under load and no-load conditions. This will involve information from datasheets, speed torque curves, other graphs and related studies.

Cost

The overall cost analysis will be based on the hardware and material required to implement the system. Again, from the previous section it should be noted that certain methods require alternative or additional hardware such as option 3. The overall cost of option 3 is estimated to be higher as it requires heat sinks to dissipate thermal energy produced during operation.

The assessment of the engineering solutions for DC motor speed control will be based on the factors mentioned above. The assessment is likely to be influenced by similar studies, datasheets, graphs, current methods used in e-bikes and user testimonials. The gathered information will be grouped based on the safety, performance and cost criteria. From here a weighted objectives chart will be created based on the relative importance of each category and a final solution should be evident. The criteria and basis thereof is subject to change before submission of the final report.

Bibliography

[1] P. Norman, "How to convert a bike to electric power: Electric Bike Conversions explained," *BikeRadar*, 09-Jun-2022. [Online]. Available: https://www.bikeradar.com/advice/buyers-guides/best-electric-bike-conversion-kits/#:~:text=There%20are%20a%20number%20of,a%20motor%20in%20the%20seatpost.

[2] "Understanding DC Motor Operation Modes and speed regulation techniques - news," *All About Circuits*. [Online]. Available: https://www.allaboutcircuits.com/news/a-basic-guide-to-dc-motors-types-of-motors-operation-modes-and-their-applications/#:~:text=There%20are%20three%20main%20ways,control%2C%20and%20armature%20resistance%20control.

[3] "Speed control of D.C. Shunt Motor: Flux control," *Electrical engineering interview questions*. [Online]. Available: https://electricallive.com/2015/02/speed-control-of-dc-shunt-motor-flux.html.

[4] "Applied Voltage Control Method of DC Motor," *Electrical engineering interview questions*. [Online]. Available: https://electricallive.com/2015/02/applied-voltage-control-method-of-dc.html.

[5] “Armature voltage control method or rheostatic control of DC Motor,” *Electrical engineering interview questions*. [Online]. Available: https://electricallive.com/2015/02/armature-voltage-control-method-or.html.