Electric Motorcycle Test Station

Andrew Copeland, Ethan Griffith, Jonathan Haas, Aaron Littleton, Dylan Scruggs, Branson Stephens
Electrical and Computer Engineering Department
Tennessee Technological University
Cookeville, TN
awcopeland42@tntech.edu, ecgriffith42@tntech.edu, jdhaas42@tntech.edu, ajlittleto42@tntech.edu, dascruggs42@tntech.edu, bkstephens42@tntech.edu

I. Introduction

The use of motorcycles in developing countries has become one of the main sources of transportation as 88% of the worldwide two and three-wheelers are found in low- and middle-income nations [1]. However, the price of owning a gas-driven motorcycle can become overwhelming and cause financial issues for users within these nations. In response, manufacturers have shifted their focus to producing electric vehicles (EVs). Although shifting to lower maintenance and fuel costs, recent statistics show that EV bike prices directly reflect the most sought-after characteristic: range. Displayed in figure 1 is the ratio of dollars per kilometer for the top 10 electric motorcycles with the best range, ranked by TopSpeed, in 2023 [2]. As seen from this, consumers must fork over, at minimum, $50 per kilometer of range in these bikes. To address this expense, Proton Power is designing an EV motorcycle that will travel 400km on a single charge at a considerably lower price of $10,000 ($25 per kilometer). To aid this production, this project proposes creating a dynamic data acquisition (DAQ) test station. The application of dynamic data acquisition is frequently used amongst various testing technologies as it allows for ensured accuracy and reduced errors. One prominent example of DAQ is its implementation into dynos. Alike dynos, this project will test the capabilities of the motorcycle and output them to a real-time display. In addition to DAQ technology, this project proposes that the testing center also supply power to the bike. As a result of this power supply, additional tests can be run on consumption and other significant variables. Through the coaction of these two applications, this project presents a system that will allow Proton Power to further expand the capabilities of a low-cost EV motorcycle, specifically the range.

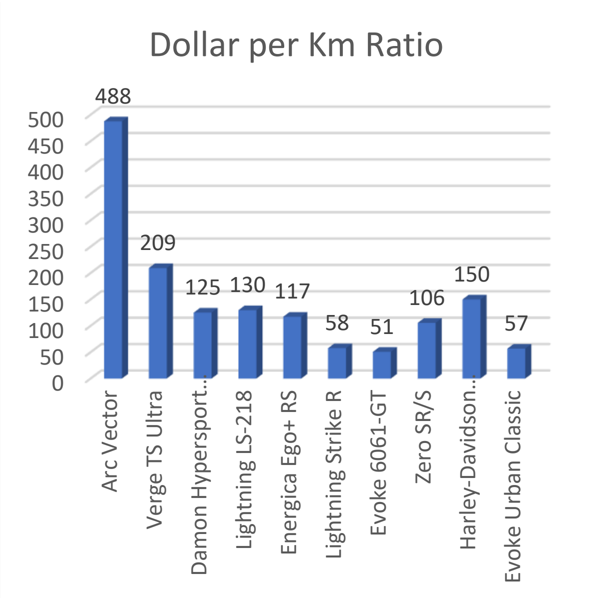

Fig. 1. Dollar per kilometer for notable electric motorcycles [2]

II. The Problem

Over recent years, the push to shift towards the use of EV vehicles has substantially risen (Fig. 2.) [3]. With this, extensive tests, to ensure product quality, must be conducted. In most circumstances, a chassis dyno is used to extract the desired characteristics. These features being measured consist of properties such as torque output, horsepower, air/fuel ratios, oil temperature/pressure, and water temperature [4]. However, when applying the same system to an EV vehicle, almost all these combustion engine specifications are not needed. From this problem stems the proposal of creating an EV-rated test station. This project will allow for efficient, accurate testing to be completed on EV-specific components to grant the ability for bike enhancements. To further expand the bike's ability to be improved, a mathematical model, once producing an operating system, will be created. This will allow for the derivation of equations to be used to simulate different inputs' outputs. To attain this solution, various problems must be addressed such as measuring torque/acceleration/power/ etc., sensor selection, powering the EV bike, data acquisition/analysis, and simulating different road grades. Each of these issues will be addressed in compliance with the standards and constraints set by the stakeholders.

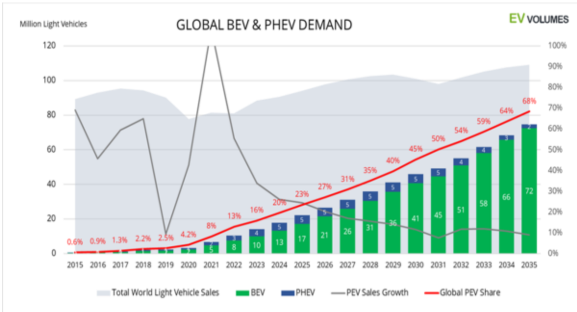

Fig. 2. Global EV demand [3]

A. Background

1. *Measuring torque, acceleration, power, etc:* To provide an accurate mathematical model of the function of an electric motorcycle, one would need to obtain an array of abundant information from the bike. Torque, acceleration, and angular velocity are just a few examples of common parameters tested using a chassis dynamometer [5]. Dynamometers (dyno for short) typically measure torque by using a device called a torque arm, which measures the force needed to move the dyno (with a load cell) [6]. This value can be output by the load cell to any microcontroller. The acceleration of a bike can be measured simply with an accelerometer attached to its wheel, and it could also be measured using a wheel

speed sensor by taking the derivative with respect to time. To measure power, there is a formula that can be used with torque and rpm as parameters:

$$HP = \frac{(Torque_{ft-lbs})(Speed_{RPM})}{5252}$$

RPM (revolutions per minute) of a motor is another measurable parameter that can be found with a tachometer, either electrical or mechanical.

2. *Sensor selection:* To gather specific bike measurements, an assortment of sensors must be used. However, selecting the sensor most suitable for the element being measured is a difficult task. The first step in choosing the correct sensor is understanding the two main applications. Microcontrollers accept, based on their input, two main types of sensors: digital and analog [7]. Each presents its own advantages and disadvantages. Of these applications, digital sensors are favored for their precision, accuracy, and adaptability [8]. Digital sensors allow for information to be digitally converted from analog physical data to discrete values and then communicated. This is done using digital components such as logic gates and chips. The result is then, in most cases, provided in terms of binary output. Unlike digital, analog sensors provide indiscrete, continuous signals. These signals are precise and directly proportional to the unit being measured [8]. To extract, analog uses components found in traditional circuits such as resistors, capacitors, inductors, and more. Scenarios in which real-time data is required are where analog interfacing is most found as the output is constantly changing.
3. *Powering the EV bike:* Being able to run tests over an extended period is a crucial factor in understanding the bike's performance. To allow this, a power supply can be implemented into the system to continuously supply power to the bike. With the specifications of the bike, a DC voltage is required to correctly input a power source. This requirement can be met by using an AC-to-DC power supply (given the test station is receiving AC input). Two main types of AC to DC power supplies are used: linear and switching. For a linear supply (shown in Fig. 3), AC-supplied input is converted to DC by using a transformer to reduce the AC input to a usable value for the intended application. The reduced voltage is then rectified and converted to a filtered DC value [9]. For a switching supply (shown in Fig. 4), the process of reducing the input voltage is eliminated and is instead rectified and filtered at the input. Then, the converted DC value goes through a chopper to convert voltage into a high-frequency train [9]. This wave then is converted back to DC voltage through another rectifier and filter. Within this design, an isolation transformer is used to prevent dangerously high voltage from passing to the output. Between these two different processes exist different advantages and disadvantages. Linear power supplies require large, heavy transformers, whereas, switching supplies use much smaller, lighter transformers. Switching supplies also prove more efficient as linear supplies lose more energy as heat [10]. However, linear supplies have more elementary circuits, causing them to cost less, than switching supplies.

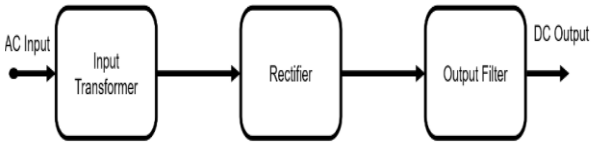

Fig. 3. Linear AC/DC Power Supply Block Diagram [9]

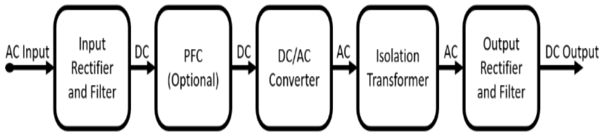

Fig. 4. Switched-Mode AC/DC Power Supply Block Diagram [9]

4. *Data acquisition/analysis:* Once a sensor has gathered information and outputted it to a microcontroller, the input must be processed. Different sensors measure different information; therefore, the data must be processed in the correct way to allow output in the most usable form. This process typically begins with an analog signal being converted into a digital signal using an ADC (analog to digital converter). Analog signals must be converted to digital signals for the microcontroller to be able to store and "understand" the data being sent in [11]. Depending on the type of output the sensor uses, the controller will have to be programmed to convert the value it receives (voltage for example) into a corresponding unit. From this point, the data can be output onto visual tools such as graphs or charts where it will be easier for a user to decipher what the sensor is conveying.
5. *Simulating different road grades:* When testing any type of vehicle, it is important to test the effect of different inclines and declines. The most common way to simulate this is by using a chassis dynamometer. Without adding any extra mechanical parts to a dyno, the road grade can be simulated by taking the 0% grade data and having software alter it based on the desired slope. Another way dyno companies address this is by adjusting the load resistance, with a motor, applied to the wheel (one company refers to this as "load mode" [12]). This resistance, when increased, raises the engine demand to simulate uphill. To simulate a degrade, the motor supplies rotation to the rotating cylinder. However, this requires calibration, so the operator knows what resistance refers to what road grade. Aside from the typical chassis dynamometer, car companies have simulated steep grades using a sled dynamometer [13]. This is a device (like a trailer) pulled by the vehicle that with the ability to change its own weight. This is done by adjusting electromagnetic coils in the trailer that make it easier or harder to pull, much like driving up a hill. This allows testing automobiles on different grades while on flat ground.

B. Stakeholders

This project will have two types of stakeholders. There are direct stakeholders who will be able to edit the GitHub repository, have meetings with the team, and have direct input on the project. There are also indirect stakeholders who are identified as being impacted by the project but will not have direct input on the project itself.

Direct Stakeholders

- Proton Power
- Supervisor, Professor Roberts
- Project Team

Indirect Stakeholders

- Consumers of the product
- General public by reduced emissions and noise pollution.

C. Specifications

The customer for the project, Proton Power, has verbally expressed some requirements that they have for the motorcycle testing station. The motorcycle they want to test is a Bob Eco two-wheel electric motorcycle.

1) Power the motorcycle: While the motorcycle is being tested on the stand, it should be powered using an external power source. The typical standalone power for the motorcycle discussed is a battery providing 65 volts/10 amps (see appendix figure 8).

2) Mobile Stand: Proton Power requests that the testing stand be a non-permanent structure. This will allow them to move it if they ever need to. This also allows the team to build the testing stand on Tennessee Tech's campus.

3) Obtain testing metrics: The testing stand needs to effectively obtain values for, specifically, the test article's torque, acceleration, and velocity. Other additional data will be tested to allow for an accurate modeling of the tested motorcycle's dynamics. This stand will also need to measure the inputs that relate to the output's testing metrics. An extra request made by Proton is to have the stand simulate different road conditions for the bike, referring to road grade/roughness.

4) Display testing metrics: The testing stand will also need to take the values tested (inputs/outputs) and display them visually as the bike is running. They request this be done using software-aided graphs or charts.

5) Obtain a mathematical model: The goal of the testing stand requested by Proton Power is to make an effective model of the functions of this electric motorcycle; therefore, they have requested that a mathematical model for the Bob motorcycle be generated.

6) Operate safely: The customer has clearly stated they need the testing stand to operate safely and abide by all relevant codes and conducts.

D. Constraints

The constraints that define the scope of the project and deliver on the expectations expressed by the customer are that the test stand design shall:

1. have a footprint that the testing apparatus can occupy in the Proton Power factory.
2. be able to be transferable and not permanently fixed to one location.
3. be able to safely operate the motorcycle up to speeds of 60 km/hr.
4. be able to monitor temperature effects on the bike and subsystems to prevent damage from excessive temperatures due to the testing environment.
5. capture and display relevant testing data in real-time and be transferable.
6. be able to fully operate remotely.
7. be able to supply the motorcycle with 65VDC with a 10A capacity.
8. be able to simulate various vertical inclines/declines up to ±19 degrees.
9. comply with all relevant codes and standards listed in Section E below.

E. Standards

Within the IEEE, NFPA 79, NEC, IEC, and OSHA codes, a comprehensive list of possible standards and regulations is provided that must be complied with. Below these are listed but not limited to:

NEC 310-16, National Electric Code Wire Current Ampacity Table – This standard will be used for determining conductor sizes. It provides comprehensive guidelines for the sizing of conductors based on the amount of current they can hold, the voltage rating, and the insulation type that is used. Adhering to this standard will ensure that the conductors used are appropriately sized to handle the electrical loads while maintaining safety and reliability.[14]

NEC 430, Motors, Motor Circuits, and Controllers - This standard covers all the requirements for the installation and protection of motors and associated circuits. It provides rules for the sizing and protection of overcurrent devices (breakers) and motor controllers to ensure that all motors operate safely and according to standards. This will be a crucial aspect of the project especially when testing the attributes of the electric motorcycle's motor and motor controllers. Adhering to this standard ensures that all equipment involved with the motor and the motor itself will be operating safely [15].

NFPA 79 – 10.7.1, Emergency Stop & Stop Devices – This standard ensures that in any electrical working environment of industrial machinery, there must be a stop or emergency stop pushbutton easily accessible. This will allow for safe operations of systems in the case of emergencies [16].

NFPA 79 – 9, Control Circuits and Control Functions

– This standard covers control circuit supply, voltages, start functions, and stop functions. Section 9.2.5.4 covers emergency stop requirements [16].

IEC 62196-1 - This standard dictates how plugs, socket-outlets, vehicle connectors, and vehicle inlets are managed specifically for charging electric vehicles. With this standard, it will be ensured that the charging methods align with international safety standards. By following these guidelines, it will be guaranteed that the compatibility between charging equipment and electric motorcycles, facilitates an ideal and efficient charging process [17]

IEC 60204 - This standard is an international standard that specifies safety requirements for electrical equipment and control systems used in machinery. It covers aspects such as electrical installations, wiring, protection against electric shock, and control circuitry. Complying with this standard will ensure that the electrical systems and equipment in machinery meet safety standards and minimize the risk of electrical hazards [18].

IEEE 2700-2017 – Covers a framework for sensor performance specification terminology, units, conditions, and limits [19].

OSHA 1910.303 - This standard provides comprehensive guidelines for electrical installations in general industry. It focuses on the health and safety of all personnel and systems used. By adhering to this standard, the protection of all personnel involved against electrical hazards such as shocks, fires, and explosions will be avoided. Safety is of utmost importance so complying with these standards will be a priority [20].

OSHA 1910.147 - This standard ensures the safety of all personnel involved in any electrical work. It provides comprehensive guidelines for the control of hazardous energy sources to prevent accidental startup of machinery or equipment, which could lead to serious injuries or fatalities. By using this standard, it will establish procedures for the isolation and control of electrical energy sources during maintenance, repair, or testing activities [20].

IEC 61439 - This standard is an international standard that specifies requirements for the design, testing, and performance of low-voltage switchgear and control gear assemblies. This standard provides a safety guideline for electrical equipment used in power distribution and control applications This standard provides useful methods for the design and construction of switchgear and control gear assemblies within the test stand, ensuring the safety for operation of electrical components such as control panels, distribution boards, and power distribution systems [21].

F. *Challenges*

Some challenges will be the short time constraint and an unknown budget. This time constraint will be amplified due to the team's current limited knowledge of the project. Another challenge that is foreseen is simulating the motorcycle traveling on a non-flat road. There is also the issue of the location of Proton Power. The design of the test stand will have to take into account the space available at Proton's plant without being able to physically verify any details. Along with this, there is the major challenge of communicating with the customer, supervisor, and all of the project team members. Every one of the parties has a busy schedule, and it will constantly be a challenge to keep all on the same page in terms of the details of the project.

III. SOLUTION

A. *Unknowns*

One significant unknown for the project is the power supply for the motorcycle. The lithium-ion battery that comes installed in the motorcycle will be swapped for a solid-state battery designed by Proton Power. The specifications of each battery and how they may differ are unknown. The variance of characteristics could have numerous implications on things such as runtime, charge time, overall weight, and thermal properties. The specifications for each battery will be vital to producing an accurate software model of the motorcycle. An additional component to this unknown is the condition of the motorcycle when the team receives it and whether there will be both a battery and charger included to begin testing with or not.

Another factor unknown is the tire performance specifications. The rear tire will need predictable traction to deliver accurate metrics while operating on the dynamometer.

The vehicle's vibration during operation throughout a range of rotations per minute at an unknown intensity can cause numerous issues with electronic sensing devices and potentially also a loss of traction. The effects of vibration on the sensors of the dynamometer could range from degradation of accuracy to complete device failure. To deliver accurate measurements, these insecurities must be monitored and addressed throughout the design and testing process.

Thermal effects are also an unknown factor. The motorcycle is designed to operate in an open ambient environment with some airflow value as the vehicle is operated. While testing in a closed environment, lacking any significant amount of airflow, the increase in temperature of multiple components could create unforeseen effects. Therefore, an evaluation of components that could be prone to a negative influence of thermal effects will need to be performed, and adequate countermeasures will need to be taken.

The vehicle must also deliver metrics simulating operation on an incline or decline. The rate of incline or decline will need to be specified by the customer and the team will need to develop a design sufficient to support these requirements.

B. *Existing Solutions*

An important aspect of designing and developing the DAQ stand is to survey existing solutions within research literature, the current market, and the industry. By examining and analyzing solutions found in similar projects, a comprehensive understanding of the background information, standards, and challenges that may affect the project can be collected and better understood.

The most common method for testing different data outputs on a bike is the use of dynos. These are bike test stands that measure the engine output of the bike. These are commonly sold on the market and used for data collection for data sheets, testing to determine potential upgrades and improvements, and even for racing bikes. While some aspects of this DAQ stand will be similar to other dynos on the market, it will differ by giving specific and personalized data requested by Proton Power and having the unique feature of being designed specifically for electric bikes in the Bob Eco supply line.

Commercial Solutions

- **EASYRUN Test Benches** – These are high-quality bike stands and the mechanical design of the stand is exceptional, but they are made for racing bikes and not electric bikes. While these may be efficient for racing companies, they are not designed to test EV bikes [22].
- **BAPRO Motorcycle Dynos** – These are test stands that provide a wide variety of tests and simulations for bikes including electric bikes. It has options for both a two-roller testing system and a single-wheel roller testing system. Its main feature is specializing in providing certificates for testing that can be used when reselling. The downside to this system is since it is such a wide variety of testing not only is it extremely expensive, but it is also large, hard to move and transport, and very heavy [23].
- **LAMNEC Electromechanical Technologies** – This solution provides the unique advantage of being able to order any testing equipment needed separately along with being able to order the test stand as a whole. However, this company is based out of China and shipping test stands can be very difficult. These stands also do not measure the electrical side of the bikes only the mechanical side. The cheapest ones purchasable are over $20,000 [24].
- **DAIG4** – This smart power bench must be operated by trained personnel. It gives several engine specifications but is for mechanical engines and not designed for EVs. It provides exhaustive tests on the engine loads under specific road conditions. This bike stand is used for tuning and modifications for engines. Like with most test stands while this is a great stand for gas engines this does not transfer over to EV bikes, and it is not commercially available for sale to the public [25].

From these examples, it is clear to see that there are a few products on the market similar to the design that is going to be achieved in this project. However, while these existing products are well-designed to accomplish the desired specifications that they were intended to, they do not match the specifications and design that Proton Power wants for their DAQ bike stand. There are no commercially available products on the market that fit the exact specifications that are wanting to be achieved by Proton Power. This is the motivation to have a specific design for the DAQ stand that will be specifically tailored to Proton Power's needs.

C. Proposed Solutions

The following section will outline multiple proposed solutions to fulfill the deliverables provided by Proton Power. Given the information provided, each solution is subject to change pending a set list of design specifics. However, each presented plan is selected based on feasibility and the specifications and constraints presented previously. Additionally, all following proposals aim to minimize the previously stated risks and impacts, within listed unknowns, and deliver set measures of success.

1) Quantifying required metrics: Acquiring the required metrics with peak accuracy and precision is pivotal to reaching the optimal end product. Numerous sensors, all exhibiting different qualities, exist to generate these outputs. The first option consists of implementing various sensors to derive each measurement. This allows for all desired data to be found with the implementation or use of separate sensors. Torque, the most important measurable, has various methods of being obtained. However, the cheapest and most suitable application for this system is to use an anti-rotational torque arm with a load cell transducer integrated into the system. Additionally, acceleration can be calculated through the use of a speed sensor and calculations. Power, with these obtained results, can also be calculated. This solution produces the customer's expressed desired values at a reduced cost in comparison to other systems. One drawback to this procedure is the increased design and integration time. A second option consists of purchasing and using a rotary torque sensor to measure torque and rpm. This would simplify the process of implementing multiple sensors and still allow for further values to be computed. However, due to using a torque sensor to measure the reading from the chassis, the rpm output will actually signify the rotational speed of the tire (angular velocity). To be able to obtain acceleration and power values from this data, mathematical computation must be used to convert the angular velocity to linear velocity. This implementation, although raising the cost of the project, saves a large magnitude of time. Another alternative solution suggests that the sensors already within the bike be decoded and used to run tests. This solution would allow for a large sum of money to be conserved. However, with the deadline presented this solution currently proves to be infeasible. Building on the feasibility of each solution, both previously mentioned options are suitable given the time constraints. However, depending on the budget, the preferred method would be to use a rotary torque sensor to obtain all desired metrics.

2) Supplying power: To allow extended tests to be run on the bike's longevity, constant, consistent power must be supplied. The rated values at which the bike requires is 65 VDC with a 10 ampere capacity. In order to provide these specifications, a power supply must be used. The easiest and least time consuming proposition would be to purchase and implement a 65 volt, 10 ampere switching power supply. One vast advantage that follows the simplicity of purchasing and connecting a supply consists of reliability. Manufactured power supplies undergo meticulous tests to ensure the ability of the device. Alternatively, the ability to design and construct a power supply specific to the parameters listed is also available. This would allow for a precision factor, incomparable to off-the-shelf models, to be present. Although this would provide a device tailored to this specific project, with the time constraints and currently provided specifications this method, as of now, lacks feasibility. The cost of constructing a power supply also proves to be upscaled compared to purchasing a reliable unit. With this, purchasing a reliable power supply is justified to be the preferred, current plan of action.

3) Data acquisition/analysis: Once all the sensors/ measurement devices are in place on the stand, they will have to be read from and get the information analyzed. This can be done using microcontroller/microprocessor boards. A proposed solution to this would be to utilize two boards. All the testing information from the various sensors could be sent via wire to an Arduino-based microcontroller to begin. These boards are equipped with analog-to-digital converters which would be needed if interacting with analog sensors. However, Arduino-based boards are inferior to Raspberry Pi microprocessors when it comes to data logging and graphing [26]. Along with this, a Raspberry Pi processor is not equipped with analog-to-digital converters like an Arduino. This leads the team to propose using one of each type of board to effectively capture the data produced by the testing station. The data would be sent into an Arduino board, converted to digital if necessary, and then transferred over to a Raspberry Pi to be processed, analyzed, and displayed on a monitor of some sort. This would also allow for the data to be put into different software such as MATLAB or Python where a mathematical model for the bike could start to be created using all the various inputs/outputs. Another solution to this would be instead of using two different controller/processor boards, it is possible to only use one Arduino board for this proposed solution. It would also be possible to use a singular Raspberry Pi processor with externally connected analog-to-digital converters to interface with sensors and process data. After seeing the availability of ways to solve this problem, it can be said that this portion of the project is fairly feasible.

4) Simulating road grades: The test stand will have to simulate moving vertically to be able to acquire data at various road grades. One method will be adding resistance to the roller so there is more demand on the motor to simulate the vehicle going uphill. To simulate going downhill the team will use an electric motor that will move the roller and vehicle so there is less demand on the motor. The other option is to create a model for various road grades through real-world testing. The team will use the mathematical model to have various outputs at a given speed at a given road grade. This will involve recording data such as speed and output power of the motor at different road grades then creating a model from the test data to be able to simulate going up or downhill. The first option will cost more but will be more precise and save time compared to finding and measuring the locations of various road grades, riding it at the various road grades, and then creating a model that would not be exact due to the numerous variables active while testing. Another benefit of the first option is that something similar has already been done successfully [27]. The main benefit of creating the model would be cost savings.

D. *Measures of Success*

The following measures of success address each previously mentioned constraint in corresponding numerical order and describe how the team planned to meet each constraint and verify it was met by a given testing method:

1. The apparatus successfully fits within the intended location at the Proton Power Facility.
2. The apparatus is able to be relocated and is not permanently fixed at any location of operation. This test can be performed by moving the entire apparatus and performing all operations.
3. The motorcycle will be able to be installed, operated, and removed safely with no immediate danger to personnel. This test can be proven by the apparatus not having any pinch points or sharp edges, and the motorcycle can be safely and securely operated up to 60 km/hr.
4. The vehicle can be operated at a time and condition specified by the customer’s intended use without incurring any damage to any subsystem of the vehicle or testing apparatus.
5. The apparatus shall be able to measure rear-wheel rpm and torque. Current and voltage consumed from the drive motor will also be captured. With the data collected, speed, torque, horsepower, and rpm will be calculated and displayed in real-time. All data collected and calculated will be recorded and transferable.
6. No personnel will need to be present in or on the testing apparatus to operate all the desired functions of the vehicle during testing. Vehicle testing can be performed initially and repeatedly without any physical interaction other than the initial setup.
7. The original battery installed in the motorcycle provides 65VDC at 10A capacity. The design will need to support power at that capacity, using the factory battery or designing a power source that will be sufficient to meet these requirements. The power supporting the motorcycle can be verified at the input with a voltmeter and ammeter.
8. Be able to induce or reduce a friction coefficient to simulate a ±19 degree incline or decline.
9. Upon completion of the project the apparatus will comply with all codes and standards deemed applicable during the review and justification process.

E. *Broader Implications*

This test stand will allow for greater production and consumption of an electric alternative to a popular form of transportation. The Proton Motorcycle's main customer base is in the 3rd world. Motorcycles produce more emissions per mile traveled than automobiles, medium trucks, and buses [28]. This motorcycle will reduce emissions in these areas which will lead to an increase in health and prevent economic losses [29]. Another impact that the motorcycle will have is reducing noise pollution in the area. A motorcycle’s perceived noise is roughly double that of other vehicles at speeds of over 30 mph [28]. Replacing these with electric motorcycles will help to eliminate harmful noise production.

Another benefit will be saving money for those who purchase the motorcycle due to its light maintenance. There is no oil, spark plugs, air filters, timing belts, gearbox, or clutch in this motorcycle and this will greatly reduce the maintenance making it more cost-efficient.

The team must take note of safety in the design as this stand will involve heavy weights, moving parts, and live electricity. It must be ensured that the design is safe with implemented proper emergency stops and protections in place. This will allow those who use the stand in the future to not be placed in a dangerous work environment.

IV. Resources

A. *Personnel and Skills*

In order to create and design a successful product, it is important to have the necessary skills come from the personnel within the group. Below is a list of the team members, along with the unique skills of each member, that will contribute to making the project successful. Keep in mind that each member of the team has a similar understanding and knowledge of basic skills in electrical engineering.

- Ethan Griffith
    - PLC
    - AutoCAD
    - Circuit Design
- Jonathan Haas
    - Power Circuit Design
    - Circuit Analysis
    - Code Compliance
    - Technical Documentation
- Aaron Littleton
    - Power Circuit and Grid Design
    - C++
    - Digital Logic Design
    - MicroStation/CAD
- Branson Stephens
    - C/C++
    - Ladder Logic
    - HMI Design in Factory Talk View
- Dylan Scruggs
    - C/C++
    - Digital Design
    - Data Analysis
    - Technical writing/communication
- Andrew Copeland
    - C++
    - Microcontrollers
    - Power Circuits

It is important that all members of the team should obtain skills and knowledge about microcontrollers and sensors, as well as being able to effectively code components. Doing this will allow the team to have a good understanding of how the stand is operating and will be able to close the skill gaps that need to be filled.

This project will also be partnered with a team from the Mechanical Engineering Department. This team will use their individual skills to create a frame of the stand, as well as the mechanical operations. With this collaboration, this project will have both aspects of mechanical and electrical operations successfully implemented.

B. *Budget and Resources*

Below, in Figure 5, is the budget that is needed for the project. This is based on the materials that are needed to complete the project and the average amount that each material costs. The total budget that is needed is between $4,300 and $4,400. This amount is not entirely accurate, as this is a rough estimate being early in the design process. It is important to note that this amount is only considering components for the electrical team. The mechanical team will have their own budget for their materials.

Material	Price ($)
Microprocessor (Raspberry Pi)	$61.79
Microcontroller (Arduino IDE)	$16.88
Dynamometer	$1,366.31
MOTIX Motor Bench	$1,174.80
Temperature Sensor	$20.40
Power Consumption Sensor	$20.75
Monitor for Display	$124.71
Wiring	$60.00
Electrical Box	$139.99
Power Supply	$649.00
Unknown Components (+20%)	$726.93
Total	$4,361.56

Fig. 5. Budget needed for the project.

This project will also include the use of different kinds of software to successfully design the test stand. The design of this product will be created using AutoCAD. This will allow the team to make drafts of how the product will work and eventually the final design. The team will also use Arduino IDE to code the sensors and other components to correctly display the correct information that is needed. Another software that is needed is Raspberry Pi OS. This will allow the team to operate the Raspberry Pi and successfully implement the microprocessor. All these products are free to use for students as AutoCAD is paid for through the school, and Raspberry Pi OS is free to use. Therefore, these products do not need to be included in the budget.

C. *Timeline*

The timeline for this project features several different deadlines and time periods for what the group will be working on during that specific time. The two timelines are shown in Figure 6 and Figure 7, in the appendix. Figure 6 shows the deadlines and tasks for Semester 1 and Figure 7 displays Semester 2. It is important to note that summer break takes place, from May 2nd, 2024, to August 22nd, 2024. There are also various other breaks that take place during the two semesters, which are shown. This will be considered a downtime for the project but can be used for additional work if necessary. The timeline doesn't include the tasks that are for each individual person in the group, but instead group tasks. With this organized and in order, it will allow the team to efficiently create the product in a span of two semesters.

V. Conclusion

Providing an accurate, functional system to aid in the production of a low-cost EV motorcycle is the preeminent goal of this electric motorcycle test station. From executing accurate measurements, correct sensor selection, sufficient power supply, efficient data acquisition/analysis, and simulating different road grades, this product will allow for a mathematical model to be produced. With this model, Proton Power will be enabled to confidently construct/enhance a successful high-range, low-income EV motorcycle.

VI. Works Cited

References

[1] "Motorcycle use in the Americas," Pan American Health Organization, https://www3.paho.org/hq/index.php?option=com_docman&view=download&category_slug=factsheets-5288&alias=46060-motorcycle-use-americas-2018-060&Itemid=270&lang=en (accessed Feb. 13, 2024).

[2] R. Adihalli, "10 electric motorcycles with the best range," TopSpeed, https://www.topspeed.com/electric-motorcycles-with-the-best-range/#evoke-6061-gt (accessed Feb. 13, 2024).

[3] "EVS forecast to account for two thirds of global light-vehicle sales in 2035," EV, https://www.ev-volumes.com/#:~:text=The%20unit%20volume%20of%20global%20EV%20sales%20is,number%20of%20EVs%20in%20operation%20will%20rise%20rapidly. (accessed Feb. 19, 2024).

[4] "Dyno Testing Basics: Engine Dynos vs. chassis dynos," OnAllCylinders, https://www.onallcylinders.com/2012/05/11/dyno-duel-engine-vs-chassis-dynos-what-you-should-know (accessed Feb. 15, 2024).

[5] A. J. Martyr and D. R. Rogers, "Chassis dynamometers, rolling roads and hub dynamometers," Science Direct, https://www.sciencedirect.com/topics/engineering/chassis-dynamometer (accessed Feb. 15, 2024).

[6] "Dyno basics: How dynamometers work," DYNOmite Dynamometer, https://dynomitedyno.com/tech-corner/how-dynos-work/ (accessed Feb. 15, 2024).

[7] "An introduction to sensors and its types-analog and digital," Electronics Lovers ~ Technology We Love, https://electronicslovers.com/sensors (accessed Feb. 16, 2024).

[8] "Analog vs. Digital Sensors - Unpacking the Cost Factors," Analog vs. digital sensors - unpacking the cost factors, https://www.processsensing.com/en-us/blog/digital-versus-analog-sensors.htm#:~:text=Overall%2C%20digital%20sensors%20are%20favored,analyzed%20in%20the%20digital%20realm. (accessed Feb. 16, 2024).

[9] "Understanding AC/DC power supply: Article: Mps," Understanding AC/DC Power Supply | Article | MPS, https://www.monolithicpower.com/en/ac-dc-power-supply-basics#:~:text=By%20using%20a%20transformer%2C%20the,waveform%20quality%20(Figure%202). (accessed Feb. 17, 2024).

[10] M. P. Inc., "Linear vs. switching power supplies: Tech," Matsusada Precision, https://www.matsusada.com/column/linear_switching_difference.html#:~:text=Therefore%2C%20they%20were%20designed%20to,lose%20more%20energy%20as%20heat.&text=The%20output%20of%20the%20switching,controlled%20by%20the%20control%20circuit. (accessed Feb. 17, 2024).

[11] "Analog vs. Digital Signals: Uses, advantages and disadvantages: ," Monolithic Power, https://www.monolithicpower.com/en/analog-vs-digital-signal (accessed Feb. 17, 2024).

[12] "Software Features," Dynapack Chassis Dynamometers, https://dynapack.com/software-features/ (accessed Feb. 17, 2024).

[13] P. Strauss, "Ford Super Duty Dyno simulates mountain driving anywhere," 95 Octane, https://95octane.com/2016/04/04/ford-super-duty-dyno/ (accessed Feb. 17, 2024).

[14] NFPA 70: National Electrical Code, 2017 Edition. In NFPA National Fire Codes Online. Retrieved from http://codesonline.nfpa.org (accessed Feb. 13, 2024).

[15] National Fire Protection Association. (2020). NFPA 70: National Electrical Code, Article 430: Motors, Motor Circuits, and Controllers (2020 ed.). Quincy, MA (accessed Feb.17, 2024)

[16] NFPA 79: Electrical Standard for Industrial Machinery, 2024 Edition. In NFPA National Fire Codes Online. Retrieved from http://codesonline.nfpa.org (accessed Feb. 13, 2024).

[17] IEC "Conductive charging of electric vehicles" https://www.dalroad.com/wp-content/uploads/2016/08/Type-II-connector-product-spec.pdf (accessed Feb. 13, 2024).

[18] International Electrotechnical Commission. (2006). IEC 60204-1: Safety of machinery — Electrical equipment of machines — Part 1: General requirements (4thed.) https://www.iec.ch/scr/meetings/national/detail_2080.html

[19] "IEEE Standard for Sensor Performance Parameter Definitions," in *IEEE Std 2700-2017 (Revision of IEEE Std 2700-2014)* , vol., no., pp.1-64, 31 Jan. 2018, doi: 10.1109/IEEESTD.2018.8277147.

[20] OSHA "Occupational Safety and Health Standards" 1910, https://www.osha.gov/lawsregs/regulations/standardnumber/1910/1910.303 (accessed Feb. 14, 2024).

[21] International Electrotechnical Commission. (2019). IEC 61439-1: Low-voltage switchgear and control gear assemblies - Part 1: General rules (3rd ed.). Geneva, Switzerland

[22] EASYRUN Technology "https://www.dyno-easyrun.com/motorbike-power-test-benches/" (accessed Feb. 16, 2024)

[23] BAPRO Motorcycle Dynos "https://www.bapro.it/en" (accessed Feb. 16, 2024)

[24] JAINGSU LAMNEC ELECTROMECHANICAL TECHNOLOGY CO. "https://www.lanmec.com/enPhoto_list.asp?ClassId=60&Topid=0" (accessed Feb. 16, 2024)

[25] DIAG4 "Smart Power Bench" https://www.diag4bike.com/smart-power-bench (Accessed Feb. 18, 2024).

[26] L. Pounder, "How to use Raspberry Pi and Arduino together," Tom's Hardware, https://www.tomshardware.com/how-to/use-raspberry-pi-with-arduino#:~:text=Software%20Setup%20to%20Use%20Raspberry%20Pi%20with%20Arduino&text=With%20the%20Pi%20rebooted%2C%20open,for%20your%20board%20is%20selected. (accessed Feb. 18, 2024).

[27] M. Martinelli and M. Farrugia, "Implementing of downhill road grade on chassis dynamometer for vehicle drive cycles testing," *2022 20th International Conference on Mechatronics - Mechatronika (ME)*, Pilsen, Czech Republic, 2022, pp. 1-6, doi: 10.1109/ME54704.2022.9982950. (accessed Feb 18, 2024)

[28] M. Hernandez, K. M. Kockelman, J. O. Lentz, and J. Lee, "Emissions and noise mitigation through use of electric motorcycles," Transportation Safety and Environment, vol. 1, no. 2, pp. 164–175, Nov. 2019, doi: https://doi.org/10.1093/tse/tdz013.

[29] R. M. Candanosa, "Reducing Emissions to Lessen Climate Change Would Yield Dramatic Health Benefits by 2030", *climate.nasa.gov*. 30-Nov.-2021. [Online]. Available: https://climate.nasa.gov/news/3134/reducing-emissions-to-lessen-climate-change-would-yield-dramatic-health-benefits-by-2030/. (Accessed: 18-Feb.-2024).

VII. APPENDIX

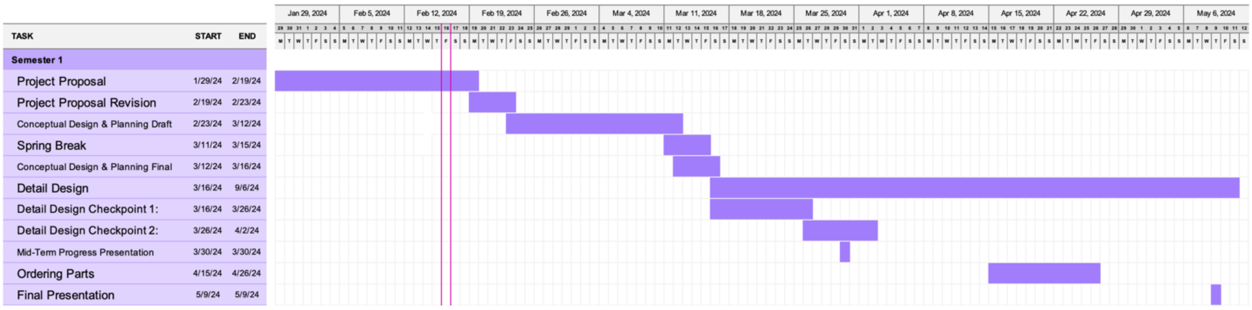

Fig. 6. Semester 1 Timeline.

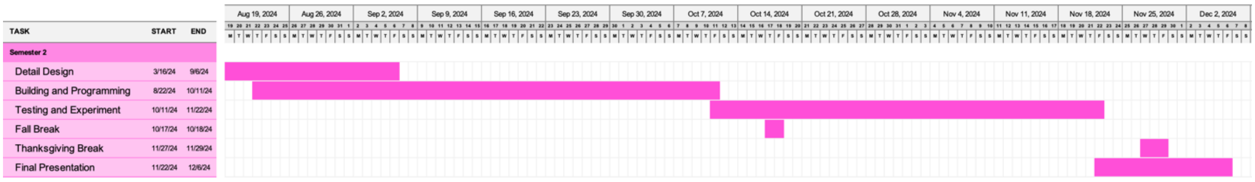

Fig. 7. Semester 2 Timeline.

Item		Content	Note
Length		1975 ng/2050mm	Without shelves/with shelves
Width		710mm	/
High		1050mm	/
Wheelbase		1300mm	/
Weight		120kg	Battery pack included (Contain the battery pack)
Seat height		815mm	Driver/crew
minimum ground clearance (Minimum ground clearance)		160mm	/
Maximum climbing angle (Maximum Angle of climb)		19°	/
Motor	Motor type (The motor type)	Wheel huh motor	/
	Rated output power (RP)	3500w	/
	The rated voltage	65V	/
Battery(Power Battery)		65V30Ah/unit	Lithium iron phosphate battery (Lithium Iron Phosphate lithium battery)
Battery pack quantity (Number of battery packs)		2(One)	Removable
Maximum speed (MAX-Speed)		60km/h (ECO) 75km/h (SPORT)	A single
Constant speed range		110KM	40km/h (ECO), single (A single) battery remaining 10% 10% battery remaining)
Working condition endurance		90km	GB14622-2016-RS1+RS1 (SPORT), A single, 20% battery remaining
Tire Size		2.75-17	front wheel
		110/70-16	rear wheel
instrument		LCD instrument	/
Braking System		Front, rear disc, CBS	/
Reverse Gear		√	/
Driving Mode		ECO、SPORT	/
communication method (Communication Isolation)		CANBUS	Instrument, battery, controller
Charger		650w (65V10A)	
Loading Quantity		SKD 105pcs	40HQ

Fig. 8. Google Translated Bob Motorcycle Specs.