Dynamometer Test Plan

ECE 492 - Spring 2015

Abstract

This document details the acceptance test plan for the dynamometer system being developed for the LFEV design project.

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Table of Contents

Summary

The dynamometer system being developed for the LFEV design project is intended to provide detailed characteristics of the Motor Controller System (MCS) over the entirety of it's operating range. These goals have been divided into 3 tiers:

Tier 1: Project Essentials

These project goals absolutely must be completed to consider the project complete. Without any one of these goals, the project will not operate as intended:

- Dynamometer Operation - The motor will spin and torque data will be gathered.
- Torque Curve Generation - The torque data will be sufficient to generate a useful curve.
- Motor Controller Operation - It will be possible to adjust the motor velocity.
- Emergency Stop - There will be an emergency stop button that cuts power to the device.
- Gear Ratio Selection - A gear ratio must be selected based on the dynamometer data.

Tier 2: Project Features

These project goals are not essential for the operation of the device, but will probably need to be implemented in the future for the LFEV project to operate according to the FEV rules:

- Safety Loop Features - The system will stop if unsafe operating conditions arise.
- Power Interface - The system will be capable of running on power from the TSI.
- VSCADA Interface - Data gathered by motor sensors will be accessible to VSCADA
- Hardware Uniformity - Hardware will abide by the rules laid out in GPR005 and the CDR.

Tier 3: Nonessential Items

These project goals are merely interesting additions the device. They will probably never need to be implemented, but doing so may ease the design process for some aspect of the project:

- Mobile Test System - The motor testing and debugging hardware will be mobile.
- Automated Tests - All tests can be run without user input.

These items in these tiers are general suggestions for the priority of the tests listed in this document. For details on how tests will be performed on tier 1 and tier 2 goals, refer to the section on the related hardware. Tier 3 goals are not listed in this document.

General Requirements

These are the most basic requirements for the operation of the dynamometer test stand. The system will be considered operational if it meets the acceptance thresholds listed in this section.

Dynamometer Operation

The most basic requirement of the dynamometer system is for it the motor to be able to operate. This implies that the motor control system has been set up and that the control interface is operational.

Testing Procedure

To test the general operation of dynamometer and motor control system, the motor must be operated for at least 10 minutes without a failure. This will be accomplished by setting the motor controller to a set speed, and allowing it to operate uninterrupted for this period.

Acceptance Threshold

For the dynamometer and motor control system to qualify as operational, the motor must not have any unaccounted-for failure during this period. Any failure that is handled by existing emergency systems will not count as unaccounted for.

Data Recording

The test stand must be capable of taking and recording readings from the onboard sensors. These will be recorded on a PC connected to the dynamometer and motor controller.

Acceptance Threshold

The data recording system for the dynamometer test stand will be considered operational if it is shown that data from the test stand is being sent to, and recorded by, the dynamometer PC.

Control Interface

The control interface, at its most minimal, must allow the user to control the speed of the motor. The control system may be either mechanical or digital.

Testing Procedure

To ensure the operation of the control interface, the system must be tested across its entire range of speeds. This involves sweeping the control interface across this range in intervals of no more than 100 RPMs.

Acceptance Threshold

The control interface will be accepted as operational if the control interface can be shown to correlate to the motor velocity at all test points. This correlation implies the completion of proper labelling and documentation of the operation of the control interface.

Sensors

The sensors incorporated into the dynamometer test stand will be logged onto a connected PC. Verification of the following parameters will be based on data recorded by this PC, and will be included in the final testing documentation.

Torque

The torque of the motor will be measured across all RPM ranges and graphed. This will be tested following the guidelines laid out in the dynamometer safety plan to minimize the risk of any physical injury or mechanical damage.

Torque Curve

The torque data gathered from the dynamometer will be sufficient to generate a torque curve for the motor over all operating conditions including various motor speeds and loads. This data will be used in simulation models of the motor controller system.

Testing Procedure

To test the torque sensor, the dynamometer will be operated across the range of motor velocities, in increments of 100 RPMs, for at least five minutes. The torque shall be measured using the provided sensors on the Huff HTH-100 and delivered to an external computer. The average value of the sensor for the last four minutes of the test shall be considered the torque value at the given velocity. A torque curve will be generated by plotting these average values.

Acceptance Threshold

The torque sensor will be considered operational if the variance between the generated torque curve and the manufacturers torque curve at all provided speeds is less than 5. The generated torque curve will be considered complete if it includes data points every 100 RPMs across the entire RPM range.

Motor Velocity

The motor velocity will be measured across all applicable ranges and will be shown to correlate to the throttle input device for all valid ranges. This will be tested following the guidelines laid out in the dynamometer safety plan to minimize the risk of any physical injury or mechanical damage.

Testing Procedure

The motor speed will be measured across the entire valid range of the motor controller. This will be done by ramping the motor velocity up through this range over the course of 5 minutes, and then down through this range over the course of 5 minutes. The motor velocity values from both the motor controller and the dynamometer encoder will be recorded to the external computer.

Acceptance Threshold

The motor velocity sensor will be considered operational if the value provided by the motor controller differs from the value provided by the dynamometer by less than 1% for all values.

Motor Current

The motor phase current will be measured continuously during operation. Due to cost, complexity, and safety considerations, this test assumes that the current sensor embedded in the Curtis motor controller is properly designed. This test assumes that if the current sensor is at least *moderately* accurate; that it is not faulty and operates to the Curtis specifications. The maximum amount of current able to be applied will be limited by the Curtis controller and the safety loop to ensure safe operation of the test.

Efficiency Curve

The data from the motor current sensor will be used to develop a motor efficiency curve. This will be used in the motor model, and will be delivered to the TSV Load Controller design group for use in load calculations.

Testing Procedure

To test the motor current sensor, the motor controller will be operated across the range of motor velocities, in increments of 100 RPMs, for at least five minutes. The motor current shall be measured using the motor controller's onboard sensor and the power supply readout. The average value of these sensors for the last four minutes of the test shall be considered the motor current at the given velocity. The data from the motor controller and the power supply will be recorded in the external computer using the software tools included for the hardware.

Acceptance Threshold

The motor current sensor will be considered operational if the motor controller current values can be shown to correlate with the power supply output current. The efficiency curve will be considered complete if it includes the motor efficiency at every motor velocity test point.

Controller Input Voltage

The voltage to the input of the controller will be monitored during operation. If at any point the voltage reaches unsafe levels the safety loop will be activated and cut the power to the system.

Testing Procedure

The controller input voltage will be measured with during all other tests by the motor controller. This value will be recorded by the external computer.

Acceptance Threshold

The controller input voltage sensor will be considered operational if the voltage is the same as the power supply voltage sensor for all data points.

System Temperature

The temperature of the system will be monitored at various points during operation, including the motor and motor controller. The data will be recorded in the external computer for display and temperature logs.

Testing Procedure

The system temperature will be measured at all relevant sensor points by both the test stand sensors and a manual handheld sensor.

Acceptance Threshold

The temperature sensors will be considered operational if the test stand sensor values are within 1% of the handheld sensor for all sensor locations.

Test Stand

The test stand is the physical unit that contains the sensors, sensor mounts, the motor controller, and the physical cabling between each component. Various aspects must be checked by inspection for safety, as detailed below.

Electrical Hardware

To satisfy GPR005 (good safety and practice) we must ensure that all electrical hardware designed must conform to the following:

Color Coding

All wires must be color coded in accordance with the following table. This table was developed using various industry standards and the specific requirements of this project, and includes the cable color, along with the size and insulation specification for all instances of the wire:

⬛	Motor Phase 1	(ungrounded)	AWG	Insulation
🟥	Motor Phase 2	(ungrounded)	AWG	Insulation
🟦	Motor Phase 3	(ungrounded)	AWG	Insulation
🟥	+90v TSV Power	(ungrounded)	AWG	Insulation
🟦	-90v TSV Power	(ungrounded)	AWG	Insulation
🟧	+12v GLV Power	(relative to GLV ground)	AWG	Insulation

🟥	⬛	GLV Ground Voltage	(relative to GLV ground)	AWG	Insulation
	⬜	+12v Digital Data Line	(relative to GLV ground)	AWG	Insulation
	🟪	Analog Data Line	(relative to GLV ground)	AWG	Insulation

MCS Cooling System

The MCS cooling system is used to control the temperature of the motor controller during high-load periods. While it may not be entirely necessary in the final motor controller design, it will be implemented to avoid any potential overheating issues before they happen.

Testing Procedure

The MCS cooling system will be tested by operating the operating the motor controller. The cooling system should be wired as to start every time the motor controller receives power.

Acceptance Threshold

The MCS cooling system will be considered operational if it is shown to pump fluid through the radiator whenever the motor controller system is operational.

Interfaces

Interfaces with various systems must be designed for the dynamometer test stand and MCS. These interfaces will be developed in conjunction with the teams in the Interface Control Document, and will be included in the final acceptance test documentation given that the respective system has also been completed.

VSCADA

It must be shown that the VSCADA system can collect real-time data from the MCS test stand. This data must be verified to be both accurate and transmitted using the protocol laid out in the interface control document.

Testing Procedure

The VSCADA interface will be tested using the tests described above for the individual sensor systems. Data will be sent to both the external dynamometer computer as above as well as the VSCADA system.

Acceptance Threshold

The VSCADA interface will be considered operational if the data received by the VSCADA system is shown to be the same as the data received by the dynamometer computer.

NOTE: This test does not verify that the information received by the VSCADA system is accurate; it merely shows that the data was transmitted accurately. Refer to the sensor tests to ensure that the data is accurate.

Tractive System Interface

The motor system will work when interfaced with the TSI or commercial power supply. The power supply shall be interchangeable without exposure to insulated wiring (see power supply switching below).

Testing Procedure

All observers will don thermal and electrical protective clothing before the test begins. While the observers are watching from the outside, Stephen Mazich will work up a nervous sweat, then attempt to swap the power supply between the MagnaPower TS series IV power supply and the TSV Load Controller.

Acceptance Threshold

If the charred remains of Steve’s body are identifiable without the use of dental records, the TSV Load Controller interface will be considered fully safe and operational. If the remains are only identifiable with the use of dental records, the TSV Load Controller system will only be considered operational. If the Acopian Engineering Center is destroyed in the resulting catastrophe, the system will be considered inoperable.

Safety

The MCS will have a safety system in place to minimize the risk of injury while operating the device. Beyond the safety plan developed in D001 - CDR, there must be an emergency stop button clearly located, and the physical design must adhere to several safety standards.

Emergency Stop

The system will shut down when the emergency stop button is pressed. This button must be hardwired into the system to minimize the possibility of failure.

Testing Procedure

The emergency stop button will be tested by operating the motor under normal conditions, then pressing the emergency stop button.

Acceptance Threshold

The emergency stop button will be considered operational if the motor shuts down without any mechanical or electrical damage when the emergency stop button is pressed. The emergency stop button must also shut down the motor directly to be considered both operational and safe.

Physical Design

A safe working environment must be established when working on the motor controller test stand. To ensure safe working conditions, there must be insulating covers over the motor power terminals, and no uninsulated wiring may be exposed to the operator during normal operation. This will be tested by inspecting the device.

Acceptance Threshold

The physical design will be considered acceptable if there are no mechanical or electrical safety hazards identifiable by a project supervisor. Individual mechanical and electrical hazards may be deemed trivial if there is a safety plan in place to mitigate the danger.

Dynamometer ATP Checklist

General Requirements	**Dyno Operation**	Motor operates	☐
	Data Recording	Sensor data is logged	☐
	Control Interface	Interface controls speed	☐
	-	Documentation describes interface control	☐
Sensors	**Torque**	Torque data is within variance	☐
	-	Torque curve has been generated	☐
	Motor Velocity	Sensors match within tolerance	☐
	Motor Current	Motor current correlates with input current	☐
	-	Efficiency curve is complete	☐
	Controller Voltage	Input voltage reading matches supply voltage	☐
	Controller Temp.	Controller temp. is accurate	☐
	Motor Temp.	Motor temp. is accurate	☐
Test Stand	**Elec. Hardware**	Color coding is accurate	☐
	MCS Cooling	Fluid pumps through system	☐
Interfaces	**VSCADA**	VSCADA receives identical data	☐
	TSI	Steve’s remains are identifiable	☐
Safety	**Emergency Stop**	Button triggers shutdown	☐
	-	Button is hardwired	☐
	Physical Design	System has been inspected	☐