Calibration and Accuracy

ECE 492 - Spring 2015

Abstract

This document outlines the various sensors involved in the LFEV, including their margin of error as well as how they are calibrated.

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Introduction

This document outlines how Dyno plans to evaluate the accuracy of the measurements made in terms of its error. This document will outline the uncertainty associated in all measurands. It will include analytical estimates of measurement uncertainty and a justification as to why that amount of uncertainty is acceptable. This document will work alongside the Acceptance Test Plan (ATP) for testing purposes to demonstrate that uncertainty verified in practice is within the analytical range and acceptable.

This document should be referred to before any modification is made to either the sensors or the software they interface with.

It is a basic truth of science and engineering that nothing can be measured with absolute certainty. There always exists some uncertainty associated with a measurement. Two types of error are typically identified. Systematic error occurs because of some inherent bias in the system, the environment, or the measurement technique, and affects the placement of the statistical mean of the measurements relative to the true value. Random error occurs because of disturbances that affect single measurements, and affects the standard deviation of the measurements from the true value. The goal of calibration is to minimize the systematic error in a given system.

The concept of calibration encompasses three procedures:

1. **Primary Calibration** - Determining the error of some system parameter with reference to a "gold standard".
2. **Operational Calibration** - Applying the error calculated during Primary Calibration to the measured values of system parameters during operation. This is necessary because the reference used for primary calibration usually cannot be accessed by the system on a continuous basis, or in a convenient manner.
3. **Calibration Verification** - Ensuring that the calibration has not drifted over time.

Dynamometer

The sensors on the dynamometer system give feedback regarding the state of the motor and the motor controller. The sensors used by the dyno team will be proven and demonstrated to be accurate within reason for the scope of their use. The sensors will also be calibrated such that the VSCADA team will be able to account for any variance in sensor accuracy if any should exist. The Motor Controller System has five sensors that need calibrated. Those measurands are: torque, motor velocity, motor current, controller input voltage, and system temperature.

Primary Calibration

Torque

Calibrated by using first principles. By hanging known weight, a known distance from the shaft while the sensor is attached and reading the output from the sensor. Using this information across a range of weights provided data. The data was analyzed and a calibration factor was determined. The data for this can be found on the website. The calibration factor was used by the software developed by VSCADA.

Motor Velocity

Completed by spinning the motor across its operational range of 0 to 6500 rpm and comparing the values read by the Huff and Curtis sensors to the handheld tachometer. The number of RPMs read by both the Huff sensor and the motor controller were then compared and a calibration factor was calculated. That data can be found on the website. The calibration factor was used by the software developed by VSCADA.

Motor Current

No primary calibration is necessary. The sensor is in place in the motor controller and its specification is not given. Verification of accuracy will be performed in Operational Calibration.

Controller Input Voltage

No primary calibration needed. The sensor is provided with the motor controller and its specification is not given. Verification of accuracy will be performed in Operational Calibration.

System Temperature

Completed by NXP and is outlined in the datasheet for the part. The sensor is linear from with one slope from 0℃ to 100℃ and with another slope from 100℃ to 200℃. This data will be used to prove accurate calibration.

Operational Calibration

Torque

The calibration factor determined in primary calibration is used in the VSCADA software to ensure accurate data acquisition.

Motor Velocity

Calibration will be performed by spinning the motor to a set number of RPMs and comparing the number set by the motor controller to a handheld Tachometer with a Certificate of Calibration and Accuracy.

Motor Current

Since a known amount of current can be supplied by the Magna Power TS Series IV comparing the current provided to the current read by the motor controller can be achieved reliably through software. A fix can then be noted and an appropriate remedy to the amount of current at the motor controller can be made knowing that the power supply is accurate to ± 0.075% of full scale current. This metric was provided by Magna Power. As long as the current measured by the motor controller is within ± 0.075% of the current provided by the power supply no correction is needed.

Controller Input Voltage

The controller input voltage can be calibrated in the same manner as the motor current. A known amount of voltage can be supplied from the Magna Power power supply. Comparing the value read by the Curtis motor controller and the value provided by the motor controller, a quick analysis of accuracy can be made. The power supply is accurate within ± 0.075% of full scale voltage. As long as the value read by the motor controller is within that range no further calibration is necessary. However if the values vary outside of that range a new range of accuracy must be developed for the motor controller based off the worst case scenario for the supplied voltage and the voltage read by the motor controller. With the accuracy of the voltage sensor determined, a new range of input voltage can be determined for the motor controller and verified from another power source.

System Temperature

Operational calibration should be minimal as the sensor should be working within the range of accuracies provided by the data sheet from the manufacturer. Corrections to the measured value can be applied based on the predictions of the known accuracies of the temperature sensor provided by the data sheet from NXP.

Calibration Verification

Torque

Verification of calibration accuracy will be performed during the ATP tests. These tests, outlined in D004, cover the full range of expected values from the system and any error will be noted and corrected during testing.

Motor Velocity

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Accuracy

Torque

Accuracy of sensor data is detailed in T001-2 Analysis. The test involved is described in the primary calibration section. It involved hanging weights and recording values. The recorded torque values were then compared to the calculated values based on the weight hung and the length of the arm. The mean of the difference between the calculated and the measured was then used to calculate the standard deviation and confidence intervals. The calibration factors used are outlined in the Torque Calibration Data document.

Motor Velocity

Accuracy of sensor data is detailed in T001-2 Analysis. The test involved applying a voltage to the throttle input, the measuring the RPM with three sources. The calibrated handheld tachometer was used as the standard. The motor controller and Huff measurements were compared to this. The motor controller proved to be very accurate at measuring the rpm.

So much so, that no calibration was needed. The mean, standard deviation, and confidence interval can all be found in the T001-2 Analysis document.

The Huff sensor proved to be far less accurate. All of its data is also in the T001-2 Analysis document. The sensor struggled to read any reliable RPM values below 1000 RPM. It also had a tendency to wander a few hundred RPM even at higher RPM. For this reason it is recommended to use the motor controller RPM values. The calibration factors used are outlined in the RPM Calibration Data document.

Motor Current

No accuracy was determined. This measurand proved to be difficult to measure directly.

Controller Input Voltage

The controller input voltage measured a constant 0.1 V higher than the power supply recorded. This did not vary, thus the standard deviation of this is zero. The confidence interval is also zero as the difference between the values did not vary.

System Temperature

The system temperature included measuring motor temp and motor controller temp. Both of these sensors were difficult to verify as they were internal to the motor and motor controller. Given that the other sensors in the motor controller were accurate, their values were accepted to be accurate. No calculations or tests were performed.