

Wykonanie pomiarów sygnałów wibroakustycznych przy stałych oraz zmiennych warunkach eksploatacyjnych na stanowisku testowym. Część II: Analiza poprawności pomiarów.  
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Dokument zawiera uzupełnienie sprawozdania nr 4 z projektu badawczego. W dokumencie przedstawiono analizę poprawności zebranych sygnałów oraz plan kolejnych prac badawczych. Dokument sporządzono w języku angielskim.

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# 1 Introduction

During the current stage of the project task, the collected data undergoes a preliminary analysis oriented towards data assessment. The data assessment includes following steps:

- verification of the test rig performance
- verification of remote speed control via Modbus TCP/IP protocol
- verification of remote torque control via Modbus TCP/IP protocol
- verification of the process parameters readings via Modbus TCP/IP protocol
- validation of the contents of the vibration signals
  - a) vibration levels
  - b) time-domain characteristics
  - c) frequency contents
  - d) time-frequency characteristics
- preliminary analysis of the wideband diagnostic indicators

## 2 Verification of the test rig performance

The test rig has undergone according to the errors pointed out during test measurements.

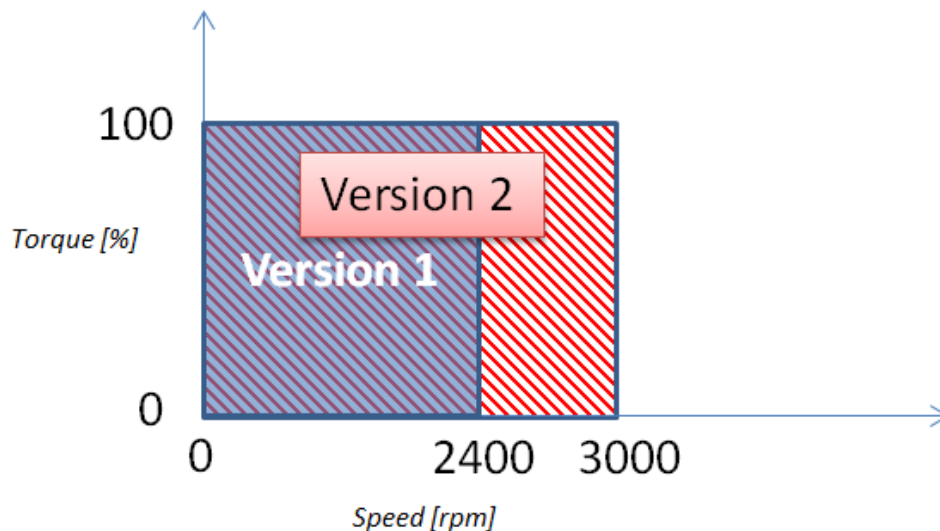


Figure. 1. Modified operational test rig ranges

After the modifications, the test rig is able to operate in the entire range of operational parameters, i.e. speed 1000rpm-3000rpm, and torque 0%-100%, comparing to the 1000rpm-2400rpm in the first version, as illustrated in Figure 1.

### 3 Verification of remote speed control

The speed profile was set to cover from 1000rpm to 3000rpm with the 200rpm step size. Figure x. illustrates the recorded speed vs. the preset speed. As observed, the speed profile matches the preset values with  $100 - ((1600-1596)/1500*100) = 99.7\%$  accuracy, which is sufficient for diagnostic purposes.

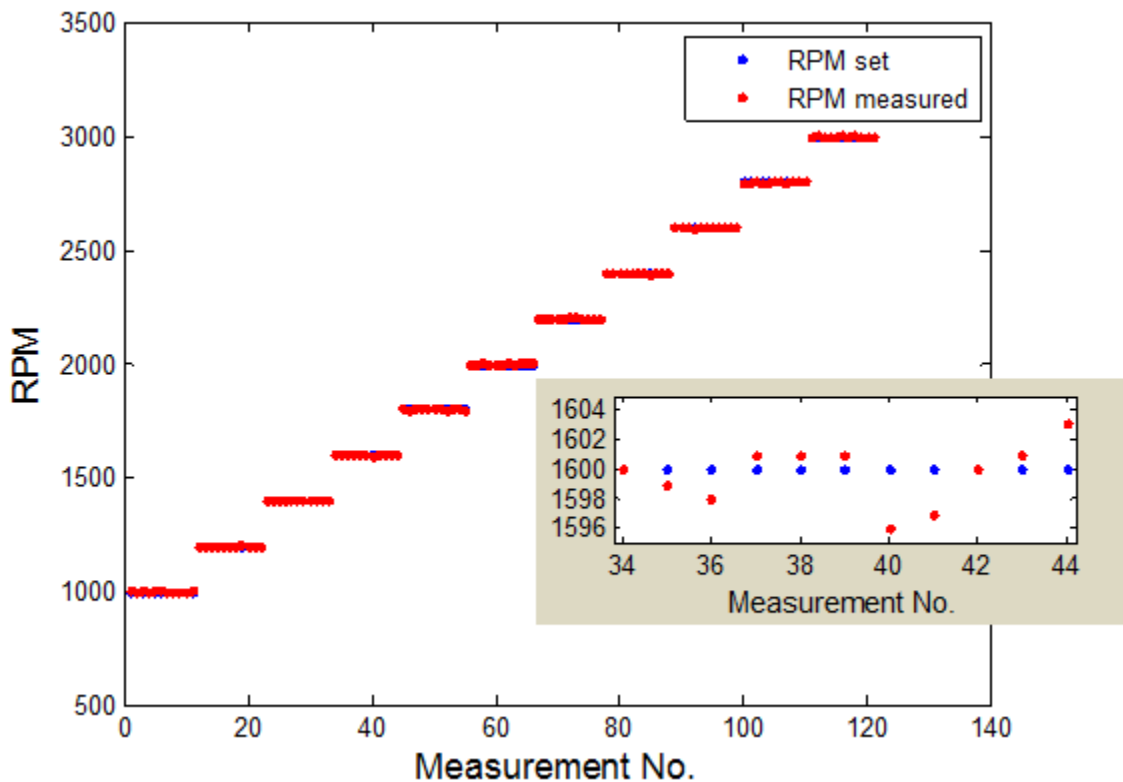


Figure 2. The measured speed values vs. preset values with additional zoomed figure on maximum observed difference, which is less than 0.3%

Taking into account possible 2% REB slip, the 0.3% difference in measurement has been accepted for further analysis.

## 4 Verification of remote torque control

### 4.1 Time response assessment

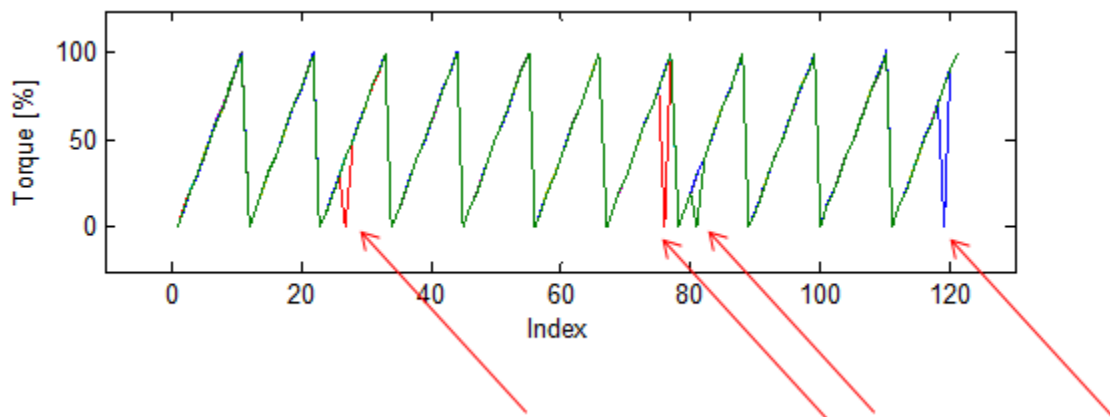


Figure 3. Representation of the measured torque values

Figure 3 illustrates the torque values registered during the 9 referential sessions. Due to inevitable measurement errors coming from machine errors, control systems errors, and external factors, certain torque values have not been registered according to preset values.

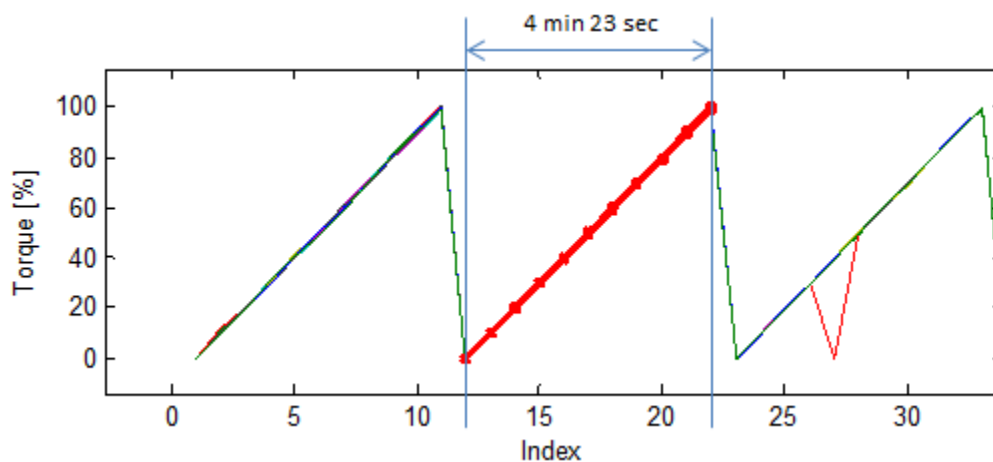


Figure 4. Measured time of each torque sequence

Namely, during 9 sessions, the torque values have reached significantly different values form expected four times (indexes 27, 76, 81, and 119). Analysis of the time of error occurrence lead to no correlation between each instances; therefore, these errors are classified as random.

During each stepwise increase of the torque values ,the torque reached values: 0, 10, 20, ... , 100 % in 4 min 23 sec  $\pm 0.2$  s. The time necessary to reach 0 torque from 100 %, and to turn from transient to stationary conditions took approximately 20 seconds.

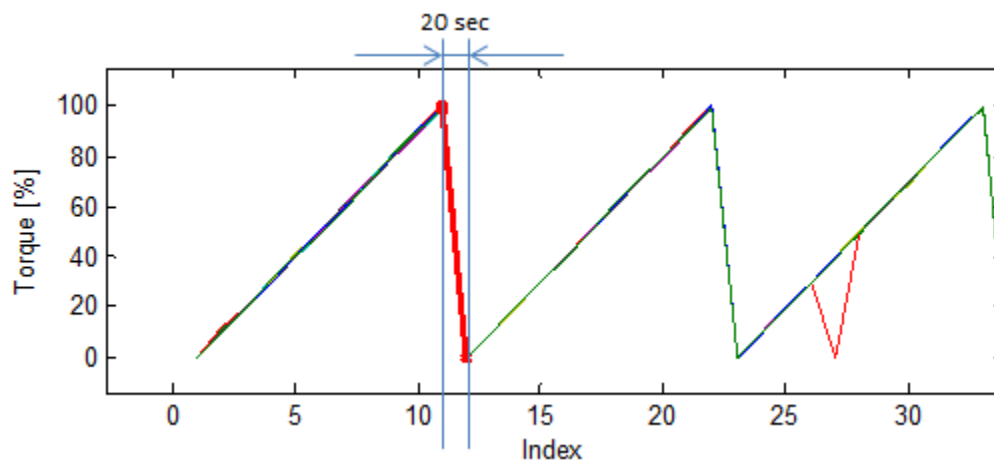


Figure 5. Measures time of sequence repertition

The analysis shows a sufficient time response of the test rig with respect to the TCP/IP protocole signals.

## 4.2 Control verification

The verification of the control signals is going to be illustrates as a straightforward difference between the input values and the recorded values. As illustrated in Figure 6, the variables are sent via TCP/IP.

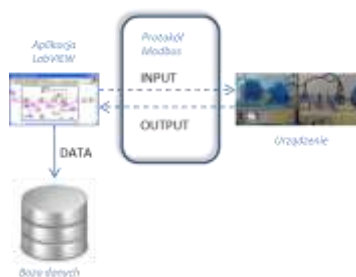


Figure 6. The control idea (from Document No. 4)

The following figures, 7, 8, and 9 show referential torque values (exact), measured values, and the difference, respectively.

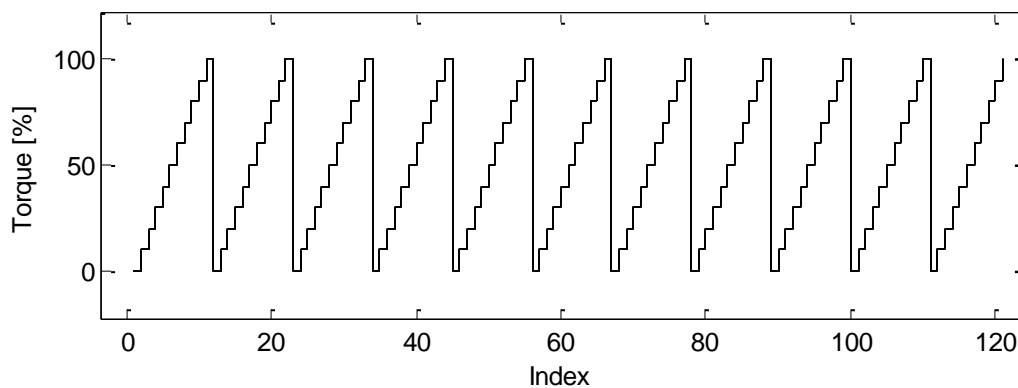


Figure 7. Reference torque values

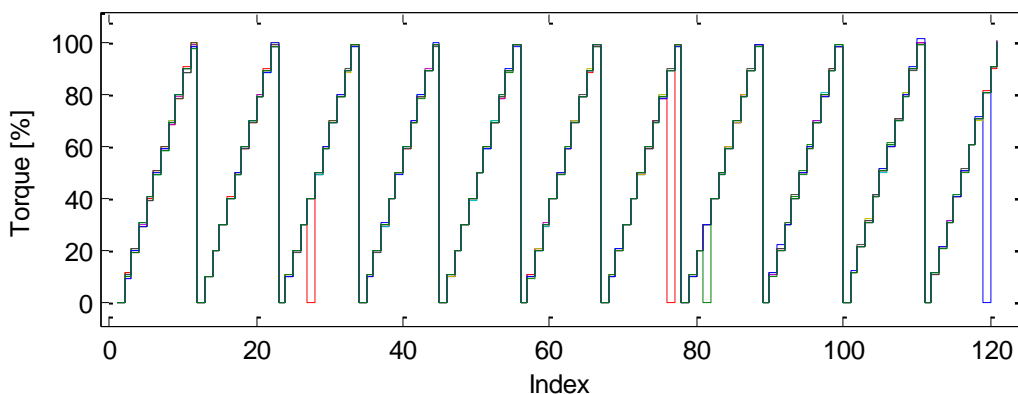


Figure 8. Measured torque values

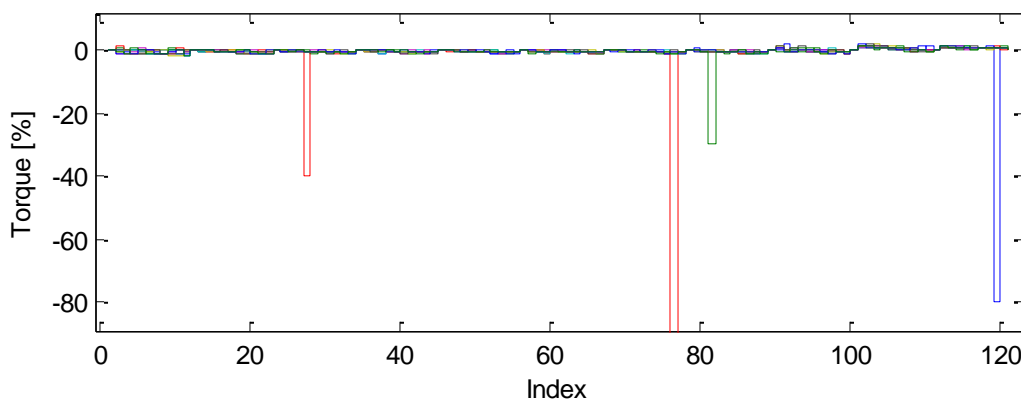


Figure 9. Difference between preset and measured values



### 4.3 Torque variance analysis

The variance analysis of the torque has been realized across two dimensions:

- for each torque level, the value has been analysed from each measurement
- for each measurement, the reached torque value has been verified across other measurement.

The figure illustrates the variance corresponding to individual series. As clearly observed, at four instances of the torque level, the machine acted significantly different from the expected value. This matrix cells are to be classified as outliers, since their variance is above 100.

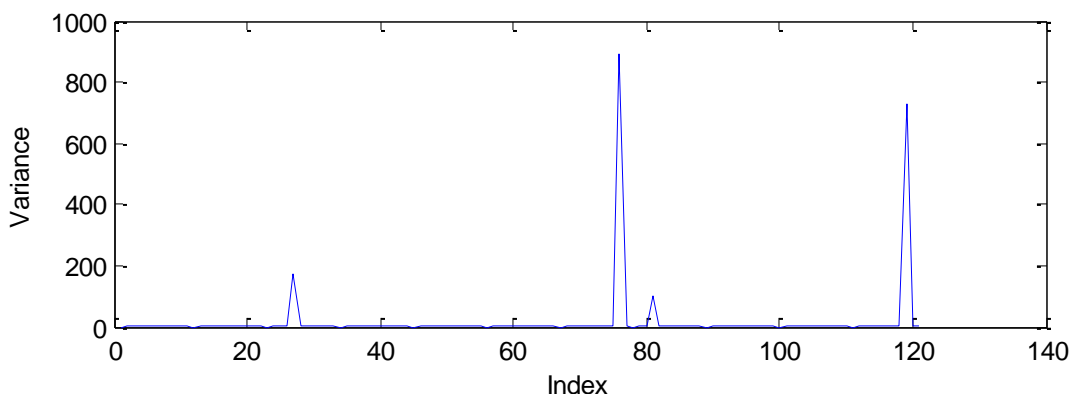


Figure 10. comparison of variance for all series

The zoomed version of the figure shows that the variance reaches a minimum values for series 30-75, which correspond to 40%, 90%, 0%, and 80%, respectively, which implies that control errors are random as well. The zoomed version of the figure shows that the variance of the difference between the preset value and the obtained value is not correlated to the value of the torque other than observation that the machine works most precisely in the medium range of torque.

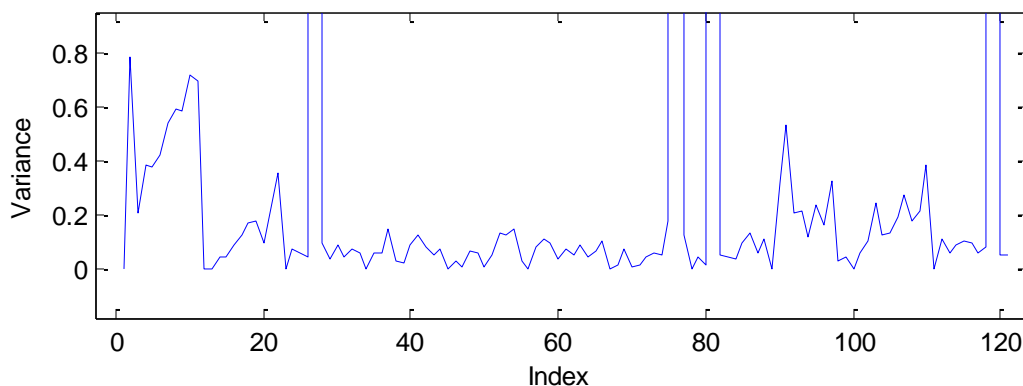


Figure 11. ZOOM of figure 10 near zero value.



## 5 Validation of contents of vibration signals

### 5.1 Vibration levels

The sensors have been placed on the gearbox and two rolling-element bearings, as specified in Document No. 4. The vibration levels for a machine in a fine condition are less than 1 [g]. Taking into account the sensors' sensitivity equal to 100 mV/g, the dynamic range of the NI card has been set to  $\pm 0.5$  [V], giving the vibration dynamic range:  $100/1000/0.5 = \pm 5.0$  [g], which:

- a) enables registering signals up to 20 times increase in PP,
- b) characterizes the data with a superior quantization level.

### 5.2 Time-domain characteristics

Figures 12-14 illustrate the time view levels for the three sensors, recorded at medium torque and different values of speed. The levels vary by over 300%, which is a very promising result in terms of the main object of the project, i.e. analysis of the dependence of the signal contents on the variable operational conditions.

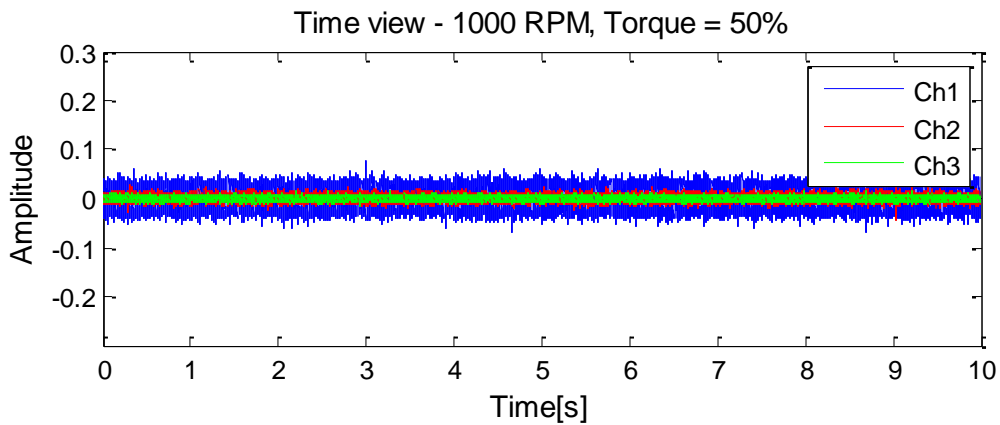


Figure 12. Time view signals for low speed and medium torque

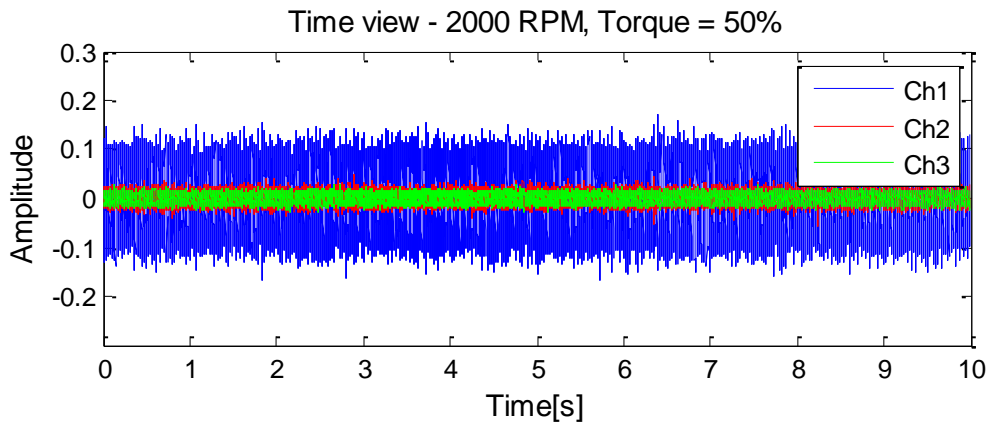


Figure 13. Time view signals for medium speed and medium torque

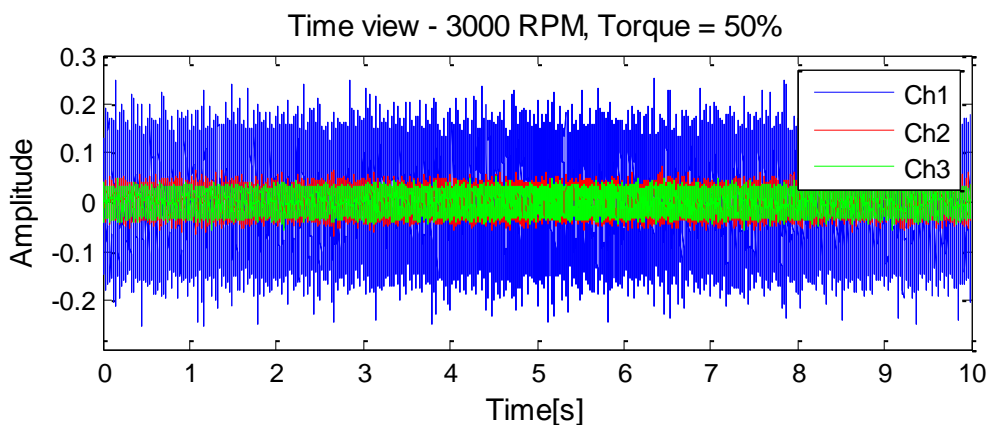


Figure 14. Time view signals for high speed and medium torque