Sensorless Anomaly Detection in Industrial Motors

ESZG628T: Dissertation

by

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ABSTRACT

Sensorless anomaly detection is a Smart Predictive Maintenance system that uses the analytic abilities of machine Learning model to monitor and predict industrial motor failures, mainly focusing on Unbalanced load and Broken bearing.

This application is based on Microchip's dsPIC33CK256MP508 16-bit device which is specifically designed for motor control applications.

Machine Learning model will be developed, trained, integrated with Motor control FoC application and programmed into the target device dsPIC. Programmed ML model will keep monitoring Motor conditions and its current values, based on current data it will notify the motor status to the user. If failure pattern detected, user will be notified with failure type along with current motor parameter values.

Sensorless Field Oriented Control (FOC) is one of the methods used to control a BLDC motor's speed and torque. Field oriented control is a technique used to generate a 3-phase sinusoidal modulation which then can be used to control frequency and amplitude. Sensorless control eliminates the position sensors and instead measures back electromotive force (EMF) to determine rotor position.

Generally, anomaly detection is done using gyro or accelerometer sensors, but using FOC will eliminate sensor cost.

The main objective of the project is to build cost effective sensorless industrial motor maintenance system and optimizing efficiency of the system by integrating Machine Learning algorithms to detect anomaly of the motor.

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Contents

1. HARDWARE AND SOFTWARE REQUIREMENTS

Following table consists of hardware and software requirements for developing sensorless anomaly detection in industrial motor application.

Serial No	Hardware requirements	Software requirements
At Motor side:		
1	Short Hurst BLDC Motor	SensiML data capture LAB
2	DSPIC33CK LVMC Board	MPLAB Model builder
3	24V power connector	MPLAB X IDE
4	Motor to board power connector	
5	UART cable	
At Dyno side:		
1	Long Hurst BLDC with encoder Motor	SciLab/X2C
2	MCLV-2 board	MPLAB X IDE
3	SAME54 PIM	
4	24V power cable	
5	Motor to board power connector	
6	Motor to board Encoder connector	
7	UART cable	

Table 1: HARDWARE AND SOFTWARE REQUIREMENTS

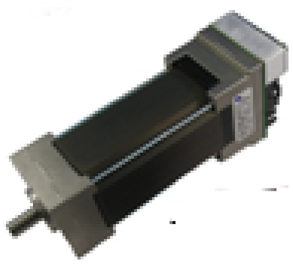
Description of each of the major components is explained below.

Hardware Requirements:

a. **Short Hurst BLDC Motor:** This 24-Volt 3-phase BLDC permanent magnet Hurst NT Dynamo motor comes with Hall-Effect sensors for 6-step commutation. It can also be controlled with a Field Oriented Control algorithm. This will be used as Test industrial motor in this application.

b. **DSPIC33CK LVMC Board**: The LVMC development board is ideal to prototype motor control applications that operate from 12 to 48 Volts and up to 10 Amps of continuous current. This board has dsPIC33CK DSC and MIC4605 MOSFET gate drivers. LVMC board is used to control test short Hurst BLDC motor. This also has UART interface circuit to connect with SensiML software for data capturing.

c. **Long Hurst BLDC with encoder Motor:** This 24-Volt 3-phase BLDC permanent magnet Hurst motor comes with Hall-Effect sensors for 6-step commutation and also has a 250-line incremental encoder for position control applications. This motor will be used to induce the failure pattern to the actual test motor.

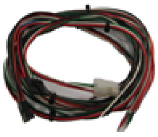


d. **MCLV-2 board:** The board is capable of controlling motors rated up to 48V and 10A (with TC1 modifications), with multiple communication channels such as USB, CAN, LIN and RS-232. This board is used to control Long hurst BLDC motor with SAME54 MCU. RS232 is used to connect the board to the SciLab in order to induce motor failure parameters.

e. **SAME54 PIM:** SAME54 PIM is mounted on the MCLV-2 board, main controller to control Long hurst BLDC motor.

f. **24V power connector:** 24V power supply to power-up both LVMC and MCLV-2 motor control boards.

g. **Motor connectors:** Power connectors and encoder connectors used to connect motors with control boards.



h. **UART (RS-232) cable:** To connect boards to PC to communicate with software Scilab and SensiML.

Software Requirements:

a. **SensiML:** SensiML is a machine learning software, will be used to capture the motor current and speed parameters when inducing failure pattern, and labeling the captured model according to failure type and building ML model. It will also be used to train the ML model. LVMC board will Communicate with SensiML through UART interface.

b. **SciLab/X2C:** This software is used to build dyno model for Unbalanced load and Broken bearing failures. Using this dyno model, different failure pattern will be induced to the test motor through MCLV-2 board. Communication interface is UART.

c. **MPLAB X IDE:** This development environment is used to generate application firmware for dsPIC and SAME54 MCUs. Hex file will be generated and programmed into the corresponding LVMC and MCLV-2 boards.

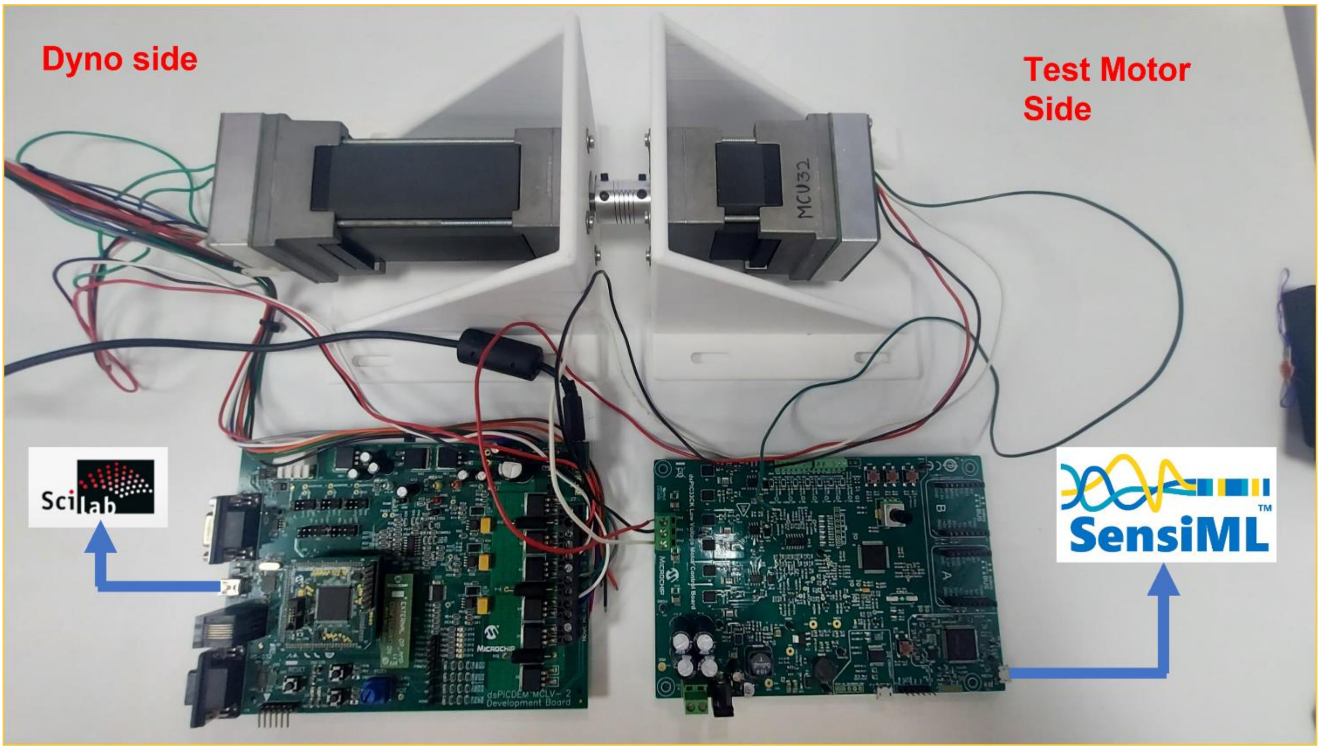
2. MAJOR MODULES

Senseless anomaly detection setup consists of two major modules.

a. Test Industrial Motor setup.

b. Dyno setup.

Both modules are shown in the below image.



The description of each of the major components is explained below:

a. Test Motor setup:

This setup represents actual industrial motor application. In this module dsPIC motor control board LVMC is connected with short Hurst BLDC motor. Field Oriented Control (FoC) motor control algorithm is used to run the BLDC motor and to control motor's speed. FoC firmware is integrated with data streaming firmware and programmed into the dsPIC33CK245MP508 device.

Streaming firmware is implemented to stream out motor current i_q, current i_d and speed parameters through UART interface to capture using SensiML software to build and train ML model.

b. Dyno setup:

This setup induces the motor failure pattern to the test industrial motor setup. This is a dynamometer control setup which uses MCLV2 board development board and SAME54 microcontroller along with long hurst BLDC motor which has Encoder.

With this setup we can apply dynamic loads such as Unbalanced load and Broken bearing to test motor. This setup is connected with Scilab and X2C software through UART interface to change load parameters on the run to induce varying failure pattern. Motor current values will vary for each of the different failure pattern values induced.

3. DESIGN CONSIDERATIONS

- Sensorless to avoid using gyro or accelerometer sensors, using FOC eliminates sensor cost. .
- Designed to detect two types for motor failures:
    - Broken bearing
    - Unbalanced load
- UART communication baud rate : 115200

4. STREAMING OUTPUT(initial version)

Below is screenshot of SensiML data capture software which shows motor current parameters i_q and i_d when small Hurst motor is running smoothly, without any issues. These are the values that will be captured to train ML model**.**

5. FUTURE PLAN

Phases	Start Date – End Date	Work to be Done	Status
Dissertation Outline	11 January 2023 – 22 January 2023	Design Review and Preparation for Dissertation Outline	Completed
Understanding of concepts	23 January 2023 – 20 February 2023	Understanding ML and FOC concepts. Analyzing suitable ML Model for required application.	Completed
Design and development	21 February 2023 – 31 March 2023	Implementing motor control FoC, Streaming and capture Firmware.	Completed
		Building ML Model and integrating them to final application	InProgress
Testing	1 April 2023 – 10 April 2023	Software Testing, User Evaluation & Conclusion	Pending
Dissertation Review	11 April 2023 – 22 April 2023	Submit Dissertation to Supervisor and Additional Examiner for review and feedback	Pending
Submission	23 April 2023	Final Review and submission of Dissertation	Pending

Table 2 : FUTURE PLAN

6. ABBREVIATIONS

Abbreviations	
FoC	**Field Orientation Control**
BLDC	**Brushless DC**
MCLV-2	**Motor Control Low Voltage version 2**
LVMC	**Low Voltage Motor Control**
ML	**Machine Learning**

Table 3 : ABBREVIATIONS