

Experimental Setup Description

System Overview

Data collection system is given in Figure 1. The system is powered by a three-phase, Y-connected AC source. This supply is connected to a three-phase frequency converter, which allows the motor to operate at variable speeds. The motor and generator are mounted on a custom-designed test rig.

The motor shaft is coupled to a single-phase synchronous brushless generator. The generator's output is connected to a resistive load (resistor bank), which can be adjusted to various resistance values.

The motor speed is controlled by selecting a reference frequency on the frequency converter. In this study, 11 different reference frequencies are considered, ranging from 45 Hz to 50 Hz in 0.5 Hz increments. Accordingly, the motor operates at 11 different speeds (rpm). For each speed, the motor is tested under six loading conditions (including no-load), which are adjusted via the resistor bank. This results in **66 unique test scenarios per machine condition**.

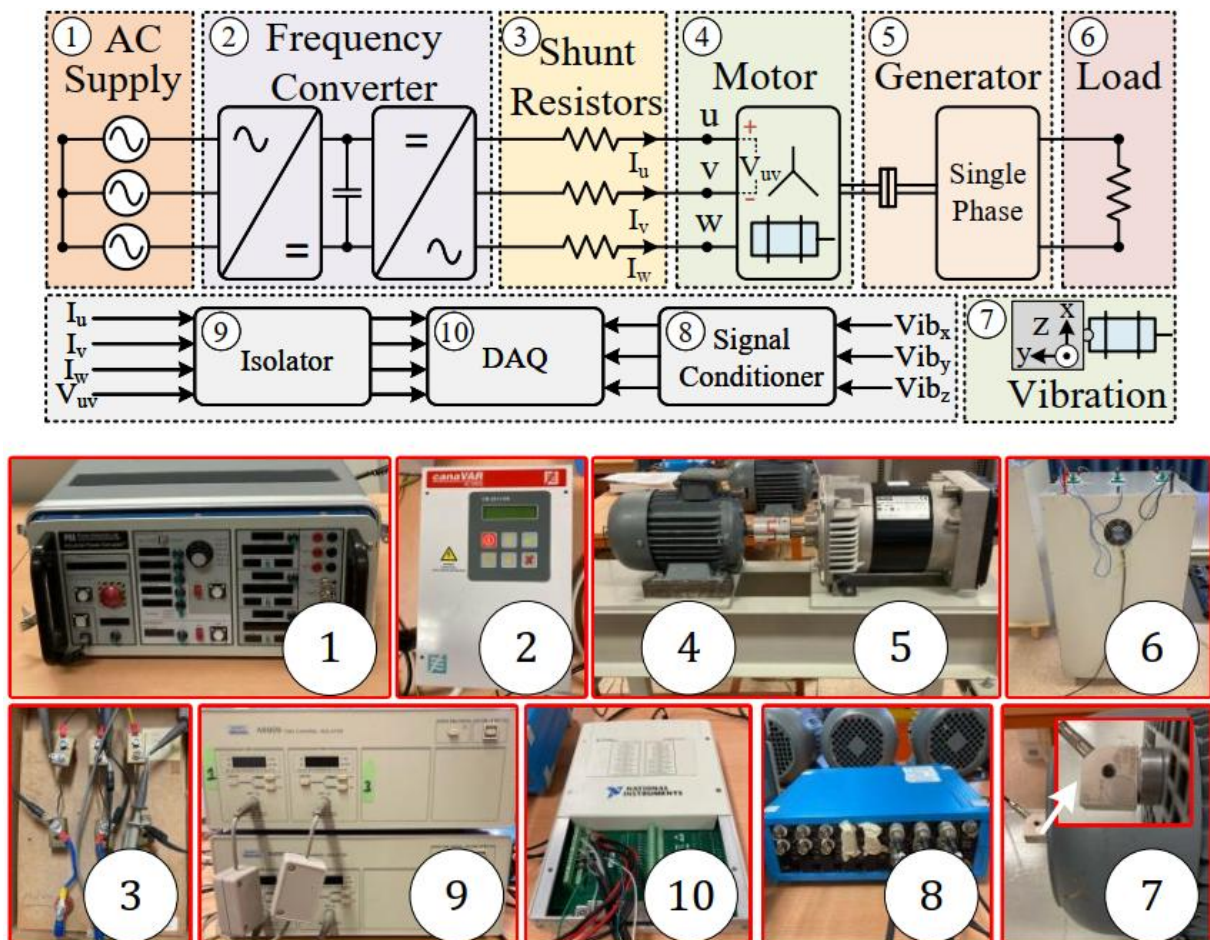


Figure 1. Data collection system overview

Resistor Bank

The resistor bank has 6 switch positions. The no-load condition corresponds to switch position 0. Switch positions from 1 to 5 correspond to resistance values of 111 Ω , 56 Ω , 38 Ω , 29 Ω , and 23 Ω , respectively.

Data Acquisition System

a) Motor current and voltage

- A three-phase shunt resistor is placed between the frequency converter and the motor to measure the current in each phase (I_u , I_v , I_w).
- Additionally, one phase-to-phase voltage (V_{uv}) is measured.
- These four signals are fed into dual-channel isolators, which provide electrically isolated and properly scaled analog outputs for the data acquisition (DAQ) system.
- Scaling: 100 mV/div for the phase currents and 200 V/div for the phase-to-phase voltage.

b) Motor vibration

- An integrated electronic piezoelectric (IEPE) accelerometer is mounted on the rear side of the motor (fan cover).
- Vibration signals are measured in the x, y, and z directions (V_{ibx} , V_{iby} , V_{ibz}).
- These signals are fed into a multichannel signal conditioner, which amplifies them (gain = 1).

c) Data acquisition card

- All seven signals are collected using an **NI USB-6221 DAQ card**.
 - Sampling rate: 35 kHz
 - Resolution: 16-bit
 - Recording duration: 20 seconds
 - Input range: ± 10 V
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The dataset was collected at the **Electrical Machines Laboratory, Eskişehir Technical University (ESTU), Turkey**.

The equipments used in the experimental setup are listed in Table 1.

Table 1. Data collection system equipment list

Equipment	Specifications	Brand & Model
AC Supply	Three-phase, Y-connected Voltage: From 100 V to 480 V Current: Up to 50 A per phase	Power Standards Lab (PSL) Industrial Power Corruptor
Frequency Converter	Input voltage: 3x380 V Output voltage: 3x 380 V Output frequency: Variable	Enko AC Drive CN 2211
Motor	Y-connected, three-phase 2-pole squirrel cage Type: AGM 90 L 2 380 V, 4.94 A, 50 Hz, 2840 rpm	Gamak
Generator	Single-phase, Type: K100 FX Synchronous brushless 230 V, 23.9 A, 50 Hz, 3000 rpm	Nsm generators
Resistor Bank	Resistance: Variable 111, 56, 38, 29, and 23 Ω	Yıldırım Elektronik
Shunt Resistors	5 A/ 60 mV	N/A
Isolators	UL1244, CSA 231, and IEC1010-1 safety standards for floating measurements	Sony Tektronix A6909
Vibration Sensor Triaxial Accelerometer	Output: IEPE Voltage sensitivity: 100 mV/g	Metra Mess KS943B100
Multichannel Signal Conditioner	8 measuring channel intended for measurement of acceleration	Metra Mess M108
Data Acquisition Card	16 Analog Input 16- Bit, 250 kS/s	National Instruments NI USB-6221

Fault Creation

To simulate common industrial fault conditions, faults were introduced synthetically in the induction motors under controlled laboratory conditions:

- ****Rotor Bar Faults:**** Three-bar (RB3) and five-bar (RB5) rotor faults were created by punching holes to the rotor bars with a drill which can be seen in Figure 2. Three and five holes are drilled respectively to two different motors over total 18 rotor bars. This produces magnetic asymmetries similar to naturally cracked or fractured rotor bars.

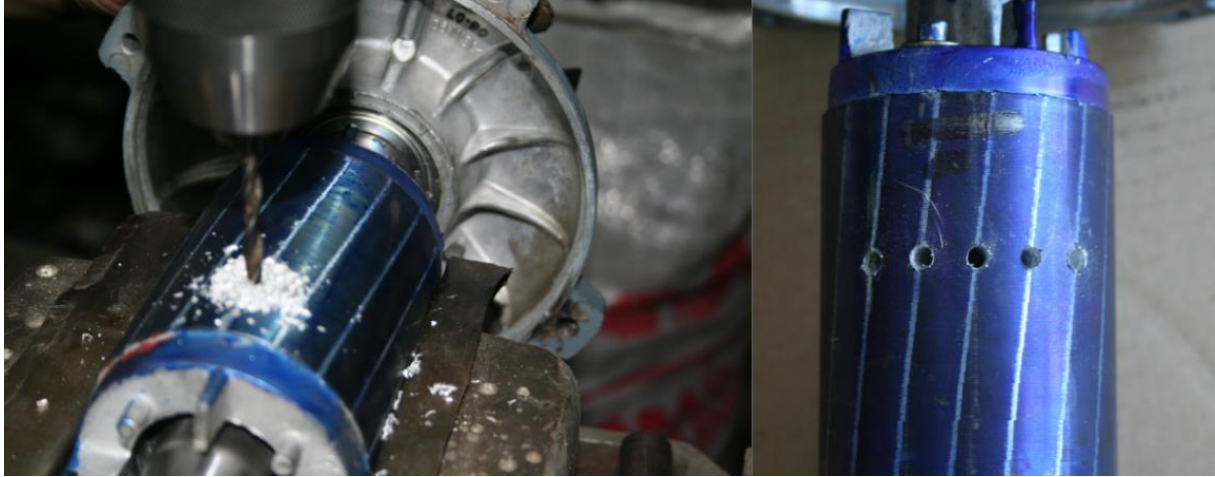


Figure 2. Realization of broken rotor bar fault

- ****Stator Winding Faults:**** Stator shorted winding (SW) faults seen in Figure 3 were introduced by intentionally damaging the insulation between adjacent turns, creating inter-turn short circuits within the stator coil.

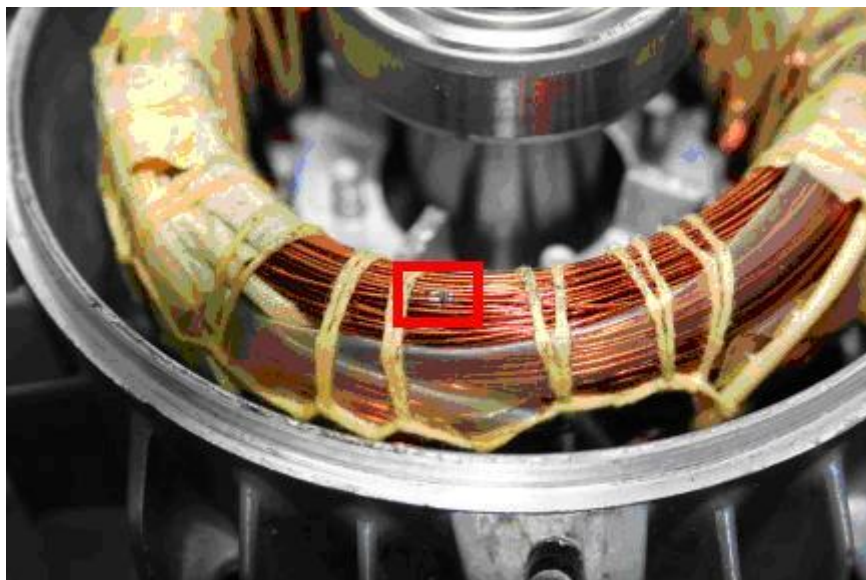


Figure 3. Realization of short circuit fault

- ****Bearing Faults:**** To replicate Bearing Ball (BB) and Bearing Ring (BR) faults, the bearings of non-operational motors are taken apart and substituted with defective bearings. The defective bearings are sourced from an actual maintenance workshop for industrial induction motors, where they are removed

from motors that have been in operation for an extended period due to problems such as noise and overheating. The faulty and unused bearings are displayed on the left and right sides of Figure 4, respectively.



Figure 4. Faulty and unused bearings

- **Healthy Reference Motor:** A healthy motor without faults was retained as a baseline for comparison against faulty conditions.

These procedures ensured that the induced faults were both **repeatable and representative** of real-world motor failures, while allowing systematic evaluation of fault detection algorithms.