Industrial applicability of Electric Signature Analysis as a diagnostic tool for Condition Based Maintenance: a case study
Introduction

Needs

- Competitiveness
- Efficiency
- Quality

% dependency

Years

electrical

mechanical

ESA
(Electric Signature Analysis)

FAIL AND FIX

PREDICT AND PREVENT

Monitoring Technique
Load and speed variations in electro-mechanical systems generally produce correlated variations in current and voltage

- The resulting time and frequency signatures reflect loads, stresses, and wear throughout the system and allow an extensive range of mechanical diagnostic and prognostic information to be obtained from a single sensor attached to an electrical line.

In electric motors, also mechanical problems generally produce variations in current and voltage

- ESA uses the line current and voltage to uncover information on both the electrical and mechanical health of the equipment.

Electric signals (current and voltage) are already monitored in a machine.

- The complexity is moved from hardware level to software one.
ESA is the procedure of capturing the equipment’s supply signals (current and/or voltage) and analysing them to detect malfunctions (not only electrical ones) or incipient faults.

**Characteristics**

- Requires only access to electric supply lines (already available)
- Diagnostic and prognostic analyses without operate inside the tested equipment (no stoppage, non – intrusive, …)
- Does not require any specific sensor for *data acquisition*
- Develop very cheap diagnostics and prognostics systems.
Case Study - methodology

PHASE 0
MAFE Methodology for the Application of Electric Signature

PHASE 1
DATA ACQUISITION

PHASE 2
FAULT DETECTION

PHASE 2
FAULT ISOLATION AND IDENTIFICATION

University of Bergamo - CELS
Research Center on Logistics and After Sales Service
### PHASE 0: Application of MAFE

#### 1) Balancing Machine Breakdown

- **Level 1 (machine):** Balancing machine
- **Level 2 (group):**
  - Locking system
  - Spindle
  - Axles movement
- **Level 3 (component):**
  - Axle X
  - Axle Y
  - Axle W
- **Level 4 (sub-component):**
  - Motor
  - Skid
  - Power cable
  - Sledge
  - Driving belt
  - Sensor

#### 2) Application of FMECA

<table>
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<tr>
<th>Failure mode</th>
<th>Level 3</th>
<th>Level 4</th>
<th>CI</th>
<th>CI</th>
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<td></td>
<td>Total</td>
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<tr>
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<td></td>
<td>Total</td>
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<tr>
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<tr>
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<td></td>
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<tr>
<td>Sensor</td>
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#### 3) Applicability of Electric Signature Analysis

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PHASE 1: Data Acquisition

Data Acquisition and Measurement Section

- Line Voltage and Current Signals
- Data Acquisition board (DAQ)
- Analog-to-Digital Conversion board (ADC)
- Virtual Instrument environment

<table>
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<th>Skewness coeff.</th>
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PHASE 2/3: Fault Detection, Isolation and Identification

Step 2: Fault Detection (Monitoring)

Step 3: Fault Isolation and Identification (diagnostics)
Conclusions

Advantages

- decrease in maintenance costs;
- substantial reduction of inspection activities on the equipment;
- increase in safety and equipment availability
- possibility to plan on time and in an efficient way maintenance actions
- contribution to the development of sustainable process and products (also energy consumption monitoring)

Future Research

- Implementing this technique in a “plug and play” hardware / software architecture
- In quality management, the comparison,
- In energy management
Future Development

**L1 – Electric Signature Toolbox**

**Purpose**
A set of software algorithms implementing the electric signature analysis using various techniques

**Input**
Electric Signature from the field

**Output**
Quantitative/qualitative indicators of the signature features

**L2 – Diagnostics**

**Purpose**
Responsible of executing the diagnostic analysis for defining the health status of the monitored equipment

**Input**
Quantitative/qualitative indicators of the signature features

**Output**
Diagnostics valuation

**L3 – Prognostics**

**Purpose**
It transforms the diagnostic valuations into a probabilistic forecast of the equipment health status

**Input**
Diagnostics valuation

**Output**
Equipment health state (probabilistic approach)

**L4 – Maintenance Policy Optimization Toolbox**

**Purpose**
It is in charge to suggest the more convenient maintenance policy considering techno / economical aspects

**Input**
Equipment health state

**Output**
Maintenance strategy definition

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Acknowledgments
This paper grounds on a project funded by Regione Lombardia titled “Sviluppo e applicabilità meccatronica della firma elettrica per innovare la diagnostica predittiva a garanzia dell’efficienza e della sicurezza delle macchine” (Development and mechatronical applicability of electric signature to innovate predictive diagnostics to guarantee efficiency and safety of the machines).