CIGRE Study committe A1

PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP

WG A1.78

NAME OF THE CONVENOR
Penrose Howard (UNITED STATES OF AMERICA)

TITLE
Guide for the Application of Electrical and Current Signature Analysis of Electric Motors, Generators and Powertrain

THE WG APPLIES TO DISTRIBUTION NETWORKS: NO

ENERGY TRANSITION
3 / Digitalization
4 / Sustainability and Climate Change
6 / Solar PV and Wind

POTENTIAL BENEFIT OF WG WORK
3 / likely to contribute to new or revised industry standards
5 / Guide or survey on techniques, or updates on past work or brochures

STRATEGIC DIRECTION
1 / The electrical power system of the future reinforcing the End-to-End nature of CIGRE: respond to speed of changes in the industry by preparing and disseminating state-ofthe-art technological advances

SUSTAINABLE DEVELOPMENT GOAL
9 / Industry, innovation and infrastructure

BACKGROUND :

Note: Electrical Signature Analysis (ESA) and Motor Current Signature Analysis (MCSA) terms have often been used inter-changeably in the past. For the purposes of this document, ESA will refer to voltage and current signature analysis and MCSA will refer to current signature analysis only.

ESA and MCSA are prognostic techniques widely used in commercial, industrial, military, and utility sectors to evaluate the condition of electrical and mechanical components of electric machines, powertrain/driven equipment. These technologies accomplish this by using the magnetic field (air gap) as the transducer which allows the technology to identify all conditions that affect the field radially and torsionally.

The recognized initial discoveries were: Oak Ridge National Labs (ORNL) in the mid-1980s, patented in 1990, as 'Motor Current Signature Analysis Method for Diagnosing Motor Operated Devices,' (patent no. 4,965,513) which describes ESA; and, Gordon University in Aberdeen, Scotland, in 1982 for MCSA using current to evaluate rotor condition. The ORNL approach included within the patent: "It has been found that the motor current noise includes the sum of all of the mechanical load changes which refer back to the electric motor drive. These are separated on a frequency and amplitude basis such that the source of various changes in load may be identified, such as periodic gear mesh loading… Thus motor current noise signatures taken at different periods during the operating life of the device may be compared to determine aging and wear or abnormal operating characteristics without interrupting the normal operation of the device as with prior analysis methods."

In 1985 through 1992, NAVSEA evaluated the ORNL method through a series of published studies including "Motor Current Analysis for the Diagnosis of Fault Conditions in a Motor Driven Pump," (1985) "Current Analysis for the Condition Assessment of Shipboard Driven Machinery," (1990), and, "Motor Current Analysis for the Diagnosis of Air Compressor Defects," (1992). In each case it was found, even with strip tape spectra, to perform exceptionally well for complete system analysis covering incoming power to driven equipment even in the electric motor bearing. Other US military studies at the time also focused on aircraft generators with studies in 2003-5 on US Coast Guard cutter generators.

ESA/MCSA were studied a number of times within EPRI starting in 1990 and continuing through 2021. One publicly available document includes TR-110899, "Predictive Maintenance of NPP Machinery Through Active/Passive Monitoring of Electric Current Frequency Spectra."

From 1991, there have been multiple commercial technologies available starting primarily with fourier transform analysis of current, voltage, torque and kilowatts. In the 1990s and into the first decade of the 2000s there were four primary ESA technologies and two MCSA technologies each focusing on fourier methods. Based on the EPRI studies, the focus was primarily on rotor testing by several of the technologies. The number of commercially available systems has increased exponentially since 2020 with cloud and AI/ML.

Multiple IEEE published independent papers and university research projects continued with a variety of additional methods which have, to date, limited to no commercial applications.

In the latter part of the 2010s, machine learning methods have been introduced that are primarily anomaly detection methods with several attempts at classification methods, but primarily relying on expert limits.

ESA and MCSA devices entered into the internet of things industry in a limited approach in the 1990s and has become more popular after 2017. In many cases, since then, some variable frequency drive manufacturers and motor control manufacturers have started building MCSA/ESA algorithms into their commercially available technologies since 2020.

Presently at least one ESA and one MCSA technology is in use with wind turbines to detect conditions such as bearings, rotor, stator, coupling, gearbox, main bearing and general blade conditions with a high degree of accuracy. Several ESA/MCSA technologies have been in use for the evaluation of power generation of all sizes.

ESA/MCSA technology includes one more interesting capability in fourier transform methods, in particular: because these models convert the data to decibels with the peak line frequency set to '0 dB,' the findings are not as effected by the load. As the data can be obtained through equipment current and potential transformers, the size and voltage/current of the machine are also not a consideration or limitation. The primary limitation is in induction machines in which resolution of the spectra becomes critical at low loads or complex systems.

A number of other methodologies are being investigated by academia and some commercial entities but primarily remain in the academic realm. These should be considered in the study.

Although the technology is relatively mature, it has seen limited application within industry primarily due to limited understanding of the capabilities and limitations of ESA/MCSA technologies in either periodic or continuous monitoring applications.

Present known standard: ISO 20958, "Condition Monitoring and Diagnostics of Machine Systems – Electrical Signature Analysis of Three-Phase Induction Motors." There is also the inclusion of the technology as a recommendation for wind power in the American Clean Power "Gearbox Playbook," 2024. It has had limited coverage in other standards due to the number of experts serving in those committees such as the retired IEEE 1415-2006.

PURPOSE / OBJECTIVE / BENEFIT OF THIS WORK :

The purpose of this WG (Working Group) is to produce a technical brochure, tutorial on the technology and applications, and webinar. These tools can be used by electric motor and generator owners to evaluate whether the technology, and which type, would be a best fit for their application. An overview as to how to interpret data for common utility and large motor users and technicians would be included as part of the development, of which there are presently limited published books (only two in publication) or literature.

The completed document would also be able to assist standards development and certification training programs. This is in demand in many vibration analysis training organizations such as the Vibration Institute, in addition to technology developers and users.

SCOPE :

This WG shall focus on a survey of ESA/MCSA technologies that are presently available, and techniques being investigated within academia. The focus on capabilities shall include:

1. Power Quality and Energy
- Power – Watts
- Power Factor, kVA, kVAR, etc.
- Voltage conditions such as voltage deviation and balance.
- Current conditions including current balance and load.
- Harmonics including supra-harmonics.
- Neutral, grounds and related currents and harmonics.
- Loose connections and related.

2. Electric Motors and Generators
- 3-phase induction machines, squirrel cage and wound rotor (i.e. wind generation).
- Synchronous machines (cylindrical, salient pole and permanent magnet).
- Across the line, electronic drive, or soft-start (all types).
- Random and form winding of any power and voltage rating.
- Mechanical conditions such as bearings, alignment/soft foot, loose or bent shaft.
- Electrical conditions such as winding defects, rotor defects, wedges, loose coils, end winding vibration, air gap concentricity.
- Energy losses by defect and associated emissions.

3. Driven Equipment/Powertrain
- Gearboxes and bearings.
- Belted applications.
- Direct coupled.
- Fans, pumps, compressors.
- Wind turbine blade balance and alignment.
- Energy losses by defect and associated emissions.

4. Storage and Communications
- Local PC and edge systems.
- Cloud-based systems.
- Wireless and cellular.
- Ethernet
- Data collection and IioT.
- Tie-in to historians and scada.
- Control and VFD installations.
- Hardware-less applications.
- Data interpretation, AI/ML and expert systems.

Remarks:

A few exclusion examples are presented below. This initial scope will be on standard machine populations with the following being potentially separate studies as these applications also exist.

a. Automotive and related
b. Machine tool and robotics
c. Traction machines (other, such as locomotive)
d. Transformer analysis
e. DC Motors and Drives

By searching e-cigre.org two documents were found which can be correlated to the proposed subject.

a) Paper A1-209-2010, I. Tsoumas and A. Safacas, “Investigation of Nonlinear and Non-Stationary Motor Current Signature Analysis Methods for Fault Diagnosis in Electrical Drives.” CIGRE 2010.

b) Paper D1-101-2020, A. Barbosa, C. Gomes, E. Nascimento, A. Barnabe, “Predictive Maintenance Based on Continuous Monitoring of OLTCs Electrical Signatures.” CIGRE 2020.

DELIVERABLES AND EVENTS

Deliverables Types
Annual progress and activity report to Study Committee
Electra report
Technical Brochure and Executive Summary in Electra
Tutorial
Webinar

Deliverables schedule

Technical Brochure	Q2	2028	Final Draft Technical Brochure
Tutorial	Q2	2028	Tutorial
Webinar	Q2	2028	Webinar

Time schedule

Q3	2025	Recruit members (National Committees, WiE, NGN)
Q1	2026	Develop final work plan
Q3	2027	Draft Technical Brochure for Study Committee review

APPROVAL BY TECHNICAL COUNCIL CHAIRMAN:
Rannveig S. J. Løken
June 05th, 2025