**TECHNICAL BACKGROUNDER - PARTIAL DISCHARGE MEASUREMENT**

**ELECTRICAL TESTING OF ELECTRIC MOTORS**

The challenge that occurs with the latest generation of electric motors is optimization of the component manufacturing in terms of efficiency, quality and costs.

The electric motor is a critical factor in the unprecedented global growth trend toward emobility. This fast diffusion of electric vehicles on a large scale puts an increased expectation of component reliability on the manufacturers. This has implications on the quality control and the process control requests of the production chain.

To meet the high-quality requirements for an e-motor, both in mobile and stationary use, measurement and testing technology must be applied systematically in the production process: first to meet the demand for safety and performance, and second to shift the production towards higher quality.

Motor testing is designed to check the integrity of an electric motor through the use of equipment that identifies potential issues within the motor. The main objective of [motor testing](https://www.edcnet.eu/) is to reveal latent problems and prevent unnecessary failure by evaluating static parameters like insulation, wire damage and electrical current leakage, as well as more dynamic parameters (such as Back EMF, NVH, speed and torque diagrams, three-phases short circuit, cogging, torque ripple,…)

The insulating system of electrical machines is a critical reliability feature since an insulation failure may result in a system breakdown. The standard electrical tests, required by regulations, are not sufficient to identify all types of failure, because many defects produce just partial discharges and these can only be identified using the partial discharge test method.

**Partial Discharge Measurement**
e.d.c., established in 1964,is a company that specializes in the design and production of testing systems for all kinds of electric motors and their components (stators and rotors), both in the laboratory and production environments. In 1998, it introduced its partial discharge measurement systems capable of recognizing the latent defects that standard tests, required by the regulations, cannot identify. It was the first European company to integrate partial discharge into production environments. The strengths of e.d.c. relies on its specialization in partial discharge measurement as e.d.c. was the first European company to integrate this technology into its production systems. More than 20 years of experience and over 8000 systems installed worldwide have made e.d.c. the global leader in partial discharge detection technology.

The e.d.c. partial discharge measurement system is based on capacitor coupling technology. As compared to antenna-type solutions normally applied in this market, the capacitor coupling technique is more sophisticated and less sensitive to external noise and, therefore, more suitable for applications in the production area. Since it does not use any external sensor, the coupling capacitor approach requires equipment which can detect the partial discharge just by connecting the terminals of the product under test with the same cables used to perform all other tests (winding resistance – AC High Pot tests – Surge Tests, …).

In the last 23 years, e.d.c. has delivered hundreds of systems with partial discharge measurement and has focused on optimizing every detail of its system, starting from the wire types, the cabling, the electronic boards, and the software. The result is a solution that is very easy to use (without any external sensors) and optimized for the production environment.

The effectiveness of the e.d.c. technology in measuring partial discharge has been validated by some of the most experienced automotive and industrial companies, who selected e.d.c. as their supplier for electrical testing of e-motors using partial discharge measurement after more than a year of test comparisons against well-known German and American competitors.

A typical fault that occurs, for instance, is when a wire touches the stack of the stator. If the wire has the enamel scratched in the contact point with the stack, even the standard AC dielectric strength test can identify the fault. However, as commonly happens, if the wire is well insulated, the voltage applied during the test -- even if quite high -- might not be sufficient to break the remaining insulation material and the fault would be not identified. With e.d.c. partial discharge measurement, carried out at the same time as the AC dielectric strength test, these defects are identified and filtered 100% of the time.

**E-motors powered by an inverter**The e-motor insulation quality assessment is an important issue, particularly for e-motors powered by an inverter since their insulation is exposed to increased thermal/electrical stresses.

The waveforms generated by the inverter [PWM] are a sequence of square waves, characterized by steep rising and falling edges, that create a fundamental sinusoid of the desired frequency. This type of waveform can give rise to greater electrical stresses than the sinusoidal power supply.

The most modern inverters have ever-higher switching frequencies, and this accentuates the reflection phenomena due to the impedance mismatch between the motor and the "cable / inverter" system. Large over-voltages can be observed at each voltage commutation, which could trigger partial discharge, especially in phase-to-phase insulation which is subject to maximum voltage overshoot.

The presence of partial discharge is the main cause of the accelerated degradation of winding insulation. The consequence of permanent partial discharge is a gradual, but continuous, weakening of functional parts of the insulation system, which leads to a complete breakdown and failure of the electric motor. That is why it’s important for there to be no partial discharge occurring in the electric motor during operation, and whythe e.d.c partial discharge testing method is so important for automotive manufacturers and Tier 1 suppliers.

**The Partial Discharge (PD) Measuring Method According to IEC 61934**
The activity under pulsed voltages is, thus, an important task for preventing motor insulation failures. The IEC 61934 standard regulates the electrical measurement of partial discharge under short rise time and repetitive voltage impulses generated from electronic power devices, to verify the insulation quality of winding materials. The e.d.c. partial discharge measurement method, compliant to this standard, allows the determination of four characteristic voltage values as PDIV (Partial Discharge Inception Voltage), RPDIV (Repetitive Partial Discharge Inception Voltage), PDEV (Partial Discharge Extinguish Voltage) and RPDEV (Repetitive Partial Discharge Extinguish Voltage) through which the insulation of the winding is clearly qualified and can be provided with production tolerances.

The range of e.d.c. products also includes solutions dedicated to functional and end-of-line testing of any type of electric motor, for in-line and off-line applications or for laboratory analysis and characterization:

* Stator Tester for production lines (wound or hairpin) that includes partial discharge measurement,
* Rotor Tester for all kinds of rotors (with permanent magnets, squirrel cage, wound),
* Automatic EoL Motor Tester (with Load/No-Load tests) for production,
* Dynamometer for motor Load Test & Life Simulation Cycles for laboratory,
* Advanced Windings and Insulation Quality Analysers for laboratory.

## Quality control of statorsQuality control of stators means checking various electrical characteristics along the entire production chain. In particular, the [insulation tests with partial discharge measurement](https://www.marposs.com/eng/application/partial-discharge-insulation-test)carried out in different stages of the process represent a key operation in assessing the quality and reliability of the component.

## Functional control of the rotorsThe [functional control of the rotors](https://www.marposs.com/eng/application/rotor-functional-testing) depends on the type of electric motor adopted and, therefore, on the rotor configuration. For squirrel cage rotors the quality control is carried out either manually or with fully automatic testing stations (for in-line integration), whose purpose is to identify defects inside the die-cast bars of the cage, such as interruptions in the material, porosities or defects in the connection to the end ring, geometric and shape errors.

## In the case of **permanent magnet rotors,** **manual benches or automatic stations** are used to perform **Back-EMF tests with FFT analysis**.

## End-of-line functional testThe end-of-line (EoL) functional test represents the key operation for quality control of the fully assembled electric motor and is responsible for the overall functionality of the product at the end of the manufacturing process.

## The methods for carrying out the functional check may differ depending on the intended use for the testing station, for analysis activities in the laboratory during the product development and process set-up phase, or for the 100% quality control at the end of the assembly line.

## During production, e.d.c. provides [complete quality control of the electric motor](https://www.marposs.com/eng/application/end-of-line-testing-of-electric-motors)**including** insulation tests to verify that the assembly operations have not compromised the perfect state of insulation, as well as a series of functional tests to evaluate dynamic parameters such as Vibration (NVH test), Dynamic or Passive BEMF with FFT analysis, Friction & Iron Losses, Zero Resolver Position and more.

## In conclusion, for emobility to continue to grow at a rapid pace, the OEM, as well as the end-user must be confident in the reliability of the vehicle functionality. As such, partial discharge measurement testing will play a crucial role as a standard testing process for electric motor manufacturers.