

PD tests can insulate against motor failures

Partial discharge testing of electric motors can reveal weaknesses in their windings before they fail. Glyn Dawson, managing director of Whitelegg Machines, explains how.

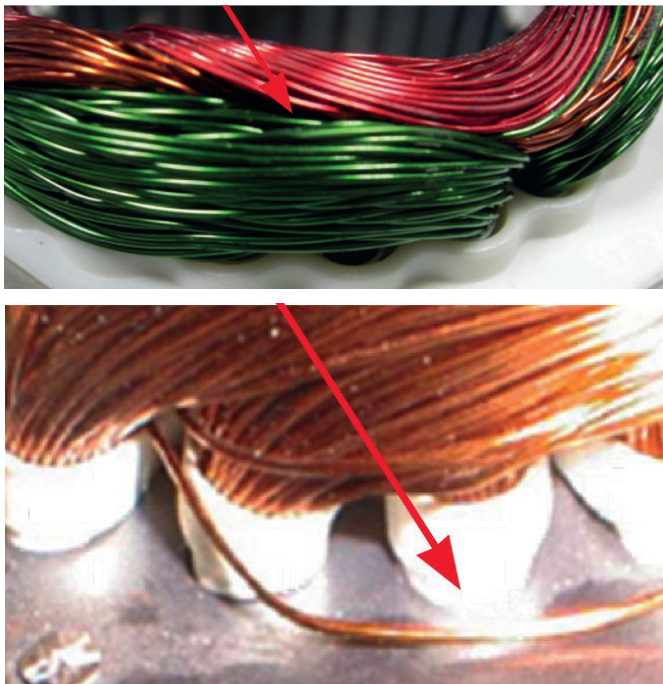


Fig 1: Partial discharge between two phases (top), and between phase and earth (bottom)

As prices of low-voltage (up to 700V) electric motors and their controls continue to fall, they are replacing pneumatic and mechanical systems at an increasing rate. The rise of electric vehicles (EVs) will further boost their numbers.

It is vital that motors operate stably, efficiently and reliably. Regulations and standards (such as IEC/TS 61934:2012 and EN 60034-18-41:2014) are aimed at raising motor efficiencies.

Partial discharge (PD) testing of a motor's insulation system is a useful tool for confirming that the motor has been manufactured to standard and to ensure that it is running reliably and efficiently. The technology is much more sensitive than standard surge testing or HV flash testing.

Partial discharges are tiny discharges that occur in overloaded insulation systems (see Figure 1). They can lead to a rapid deterioration of the insulation and to eventual motor failure.

With the ongoing pressure to cut running costs, the use of motor controls is increasing, whether in the form of servo controls, or new or retrofitted inverters. In such cases, PD testing is particularly appropriate. We are looking for insulation systems that are resistant to, or free from, partial discharge.

With the fast rise times of modern inverters, voltage peaks (overshoots) can occur at the motor connection board, causing stress to the motor's insulation. The level depends on, among other things, the length of the cable between motor and inverter. Inverters produce many voltage peaks per waveform which PD can measure.

The DIN EN 60034-18-41:2014 standard establishes a test regime for partial discharge in LV motors with operating voltages from 300–700V.

Table 1, below, shows four possible levels of motor insulation quality, although many motors will come under the extreme category because failure is unacceptable.

STRESS CATEGORY	OVERSHOOT FACTOR	IMPULSE RISE TIME (μ s)
A - Benign	≤ 1.1	0.3
B - Moderate	$1.1 \leq 1.5$	0.3
C - Severe	$1.5 \leq 2.0$	0.3
D - Extreme	$2.0 \leq 2.5$	0.3

Table 1: Levels of motor insulation quality

The choice of stress category also depends on the application. Where long motor lead lengths are used – such as with submersible pumps – the category will always be extreme because of the effect the leads can have on the voltage to the motor terminals.

The required test voltage for a particular motor can be calculated using the following formulae.

Calculating test voltages (phase-to-phase)

$$\text{Test voltage}_{\text{peak-to-peak}} = 2 \times (U_{\text{DC}} \times \text{OF}) \times 1.1 \times \text{EF}_{\text{Factor}}$$

Where U_{DC} is the internal bus voltage of the inverter, **OF** is the overshoot factor, and **1.1** is a 10% voltage increase because of voltage fluctuations which affect the internal bus voltage.

An enhancement factor must also be added, which is shown in DIN EN 60034-18-41:2014

Calculating test voltages (phase-to-earth)

$$\text{Test voltage}_{\text{peak-to-peak}} = 0.7 \times \left(\frac{U_{\text{DC}}}{(n-1)} + U_{\text{b}} \right) \times 2 \times 1.1 \times \text{EF}_{\text{Factor}}$$

Where U_{DC} is the internal bus voltage of the inverter, U_{b} is the overshoot voltage $(U_{\text{DC}} \times \text{OF}) - U_{\text{DC}}$, **1.1** is a 10% voltage increase because of voltage fluctuations which affect the internal bus voltage, **n** is the number of inverter levels, **EF** is an enhancement factor

MOTORS SUPPLEMENT

(according to Table B.2), and **0.7** is a factor for reducing voltage jumps that takes into account the capacity to the ground. Inverters have different levels and this must be reflected in the calculation:

Two-level inverter
 jump voltage_{max} = U_{DC}

Three-level inverter
 jump voltage_{max} = $U_{DC}/2$

PD testing will show up any weakness in the motor windings which will inevitably lead to failure. Motor efficiency is also affected. Tests are performed while the motor is offline, because the test device introduces a voltage into the winding. The test can be performed on the stator only and/or on the assembled motor.

PD will also show differences a motor's impregnation quality with higher PD visible on less well impregnated windings.

Whitelegg has a limited number of 190-page Test Method handbooks available, which offer a comprehensive guide to test methodologies. (www.whitelegg.com)

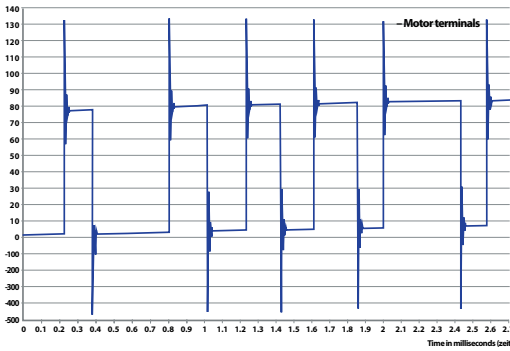


Fig 2: An example of a waveform produced by an inverter

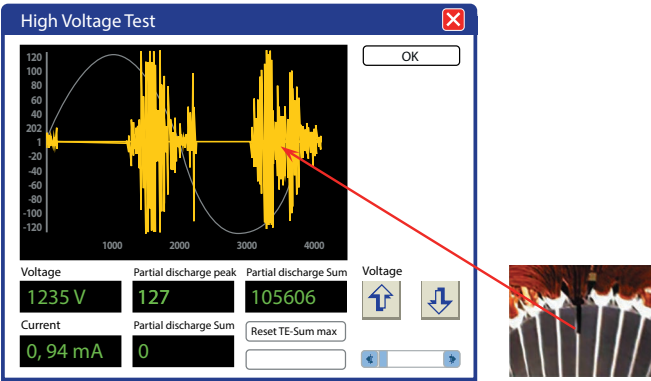


Fig 3: A PD test during a high-voltage AC test which reveals a phase-to-frame insulation problem. Such a fault would not show up using a conventional surge test of the winding insulation.

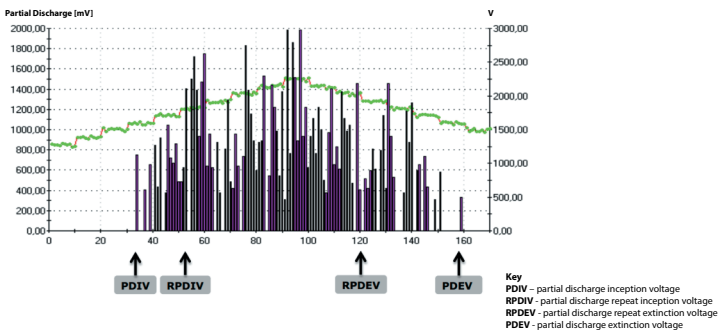


Fig 4: A typical partial discharge result.