Motor monitoring services

Early identification of potential electric motor failures ensures the reliability of critical machinery
Why test electric motors?

As production requirements drive the demand for less downtime, higher output from machinery, and lower maintenance and repair costs, monitoring the condition of equipment is becoming increasingly vital for maintenance engineers. They would prefer to plan shutdowns and maintenance programmes based upon equipment needs and condition, and to be aware of any potential problems that may lead to an unexpected breakdown. Therefore, they require maintenance tools which can provide a comprehensive condition assessment, and early prediction of faults and developing problems. Emphasis is now being placed on predictive maintenance where problems can be identified well in advance of a failure.

The use of a condition monitoring approach enables the early detection of a wide variety of faults, allowing the scheduling of corrective maintenance at a convenient time. A variety of monitoring techniques exist, with vibration analysis being the most widely used.

SKF is typically known as a provider of mechanically-related condition monitoring products and services. However, with the acquisition of Baker Instruments it enables SKF to introduce a range of electrical services that complete its offering in terms of rotating machinery performance and condition monitoring. This ensures ownership of machinery problems until resolution, with no separation between electrical and mechanical issues.

**Electrical services provided:**
- Static electric motor and generator analysis
- Dynamic electric motor analysis
- Motor current signature analysis
Static motor analysis

Reliable operation of electrical machines depends largely on the integrity of their winding’s insulation. Failure can incur high repair costs even before considering the loss to production. Over time, the insulation system of a motor or generator deteriorates through thermal, electrical, mechanical and chemical stresses; and periodic assessment of the insulation condition can determine a range of insulation problems at an early stage. This enables timely remedial action and can prevent the occurrence of failure, and uncontrolled outage of equipment.

SKF static testing provides in-depth analysis of the stator’s winding circuit and insulation, through a range of tests:

- Winding resistance to check for balance between phases
- Insulation resistance (Megohm)
- PI and DC step voltage testing to assess the ground wall insulation
- Surge testing to check for phase to phase and inter-turn defects within the windings

Site testing is typically performed at the motor control cabinet, so as to include the power cable in the test circuit. However, tests can also be made at the motor terminal box.

SKF static analysers perform the tests in specific order, starting with the low-voltage winding resistance test, insulation resistance, polarization index, DC step voltage, and finally the surge test.

The SKF Static Motor Analyzer Baker AWA combines multi-function insulation testing capabilities and computer control into a field portable instrument. Test parameters are pre-programmed to avoid operator error. The pass/fail limits, which can be set to international standards or agreed by site, eliminate all guesswork and provide guidance when assessing motor and insulation condition.

Should a test fail, the unit will stop the testing sequence. Testing will only resume once the cause of the failure has been investigated and corrected.

Tests up to 40 kV can be completed, covering both low voltage and high voltage machines. This equipment also provides computer-generated reports of the tests performed, and automatically trends the values over time.

Stock inventory motors

Stock motors are typically held to allow quick replacement on critical machines. These motors often sit in storage for years, and unless tested regularly, their condition is unknown and cannot be relied upon.

Static testing should be performed to verify condition prior to installation, but ideally also on an annual basis.

Winding resistance

This is a low voltage test (12VDC or less), using 4-wire kelvin leads for accuracy. It measures and compares the resistance of the three phases and is capable of measuring down to one milliohm. This will allow the detection of loose or corroded connections, short and open circuits. It can also indicate incorrectly wound windings, when compared to previous values. The percentage unbalance can be trended over time to detect developing faults. The test unit will correct the measured resistance value to 20 °C, which allows the readings to be reliably trended over time.

Insulation resistance (or the Megohm test)

The insulation resistance (IR) test is an accurate measurement of the ground wall insulation resistance. The test consists of applying a DC voltage according to industry standards and measuring the leakage current. The leakage current measurement is taken 60 seconds after the test voltage is reached to allow the charging current to dissipate. The IR value is calculated using Ohm’s law. The IR value is automatically temperature corrected to 40 °C. Trending non-corrected IR values over time will give skewed results due to the differences in winding temperature when the tests were performed. The test can identify:

- Damaged and burnt slot liner insulation or enamel wire
- Contamination – carbon dust, water or other contaminates
- Shorted windings to ground
- Poor cable insulation

SKF Static Motor Analyzer Baker AWA 12 kV
**Polarisation index**

The polarisation index (PI) test is an extension of the IR test and is performed to quantitatively measure the ability of the ground wall insulation to polarise. When an insulator polarises, the electric dipoles distributed in the insulator align themselves with an applied electric field. As the molecules polarise, a ‘polarisation current’ (also called absorption current) is developed that adds to the insulation leakage current. The PI test is performed at the same voltage as the IR test and takes 10 minutes to complete.

In general, insulators that are in good condition will show a high polarisation index while insulators that are damaged will not. Low PI values can indicate moisture or contamination, and also brittle insulation.

**DC step voltage test**

The DC step voltage test is typically performed at twice the motor’s operating voltage plus 1,000 volts. The test is used to verify that the insulation to earth is able to withstand the high voltage transients that motors see on start-up/shutdown.

The voltage is gradually increased over five steps until the target voltage is reached, with each voltage step held for one minute. The leakage current at each voltage step is measured and the current profile over the five steps examined. Whilst clean and dry insulation shows very linear current increase, non-linear increase would indicate contamination, moisture or ground wall/cable insulation damage.

**Surge test**

Studies have shown that 80% of electrical failures in AC motors start as inter-turn insulation weakness. These turn-to-turn faults typically progress and develop into an earth fault, but often are not detected prior to the motor failing. Paschen’s law states that in order for voltage to arc between two conductors, a potential difference of at least 335 volts is required. The required voltage will vary depending on the insulation weakness and the air gap size. During the IR, PI and DC step voltage tests, all the turns of the winding are raised to the same voltage potential, hence these tests are not capable of detecting turn to turn weakness.

The surge test works by injecting high voltage impulses into one phase at a time, creating a turn-to-turn potential difference. By testing at industry standard levels, weak turn-to-turn insulation can be detected in advance, allowing time to plan the required maintenance work. The surge test simulates the high voltage switching surges that motors see during start-up and shut-down.

![Normal waveforms](image1)

![Failed waveforms](image2)

![Normal pulse to pulse graph](image3)

![Failed pulse to pulse graph](image4)
Dynamic electric motor analysis

Generally, motor operation and performance is a response to power supply quality and load variations, both of which can be captured by measuring voltages and currents during normal motor operation.

SKF dynamic motor analysis equipment is used for the measurement of these voltages and currents. The technique uses clamp-on current transformers and voltage clips temporarily connected in the motor control cabinet (no access is required to the motor terminal box).

SKF Surveyor software is used to analyse the motor voltages and currents under normal operating condition. It then calculates further parameters including voltage and current harmonics, power, motor speed, torque, spectra, etc. Dynamic testing can be applied to both LV and HV motors, and allows a comprehensive range of variables to be monitored and used to assess the power supply quality, motor condition and performance, rotor cage condition, rotor–stator air gap eccentricity as well as load performance and mechanical influences.

Test results – good, caution or warning, are then presented using a traffic light system as shown below.

The test engineer can drill down to view further data and results to make an accurate assessment of the entire motor driven system.

The EXP4000 test unit utilises multiple tests to determine the power condition, motor health, load and energy profile for the motor using the following test domains:

- **Power quality**: Identifies over and under voltage conditions, voltage distortions as well as voltage unbalances.
- **Machine performance**: Assesses the overall motor performance with regards to thermal overheating based on load and power quality, and calculates a NEMA derating factor that reflects the true motor operating conditions.
- **Current**: Problems such as over-loading, poor connections, misconnections, iron saturation and mis-wound motors are difficult to detect without the right equipment. The EXP4000 evaluates current and current unbalances to assess the overall electrical condition of the motor/machine system.
- **Torque**: Transient conditions can easily over-stress a machine system, but can be very difficult to identify and assess. SKF’s innovative torque analysis capabilities within the EXP4000 provide the means to find torque-related problems. The torque time and spectrum signatures are used to diagnose mechanical problems, and to clearly identify transient conditions. Users can accurately identify issues including cavitation, bearing problems, mechanical imbalances, eccentricities, misaligned shafts and more.
- **VFD**: VFDs/Inverter drives pose a unique set of challenges for maintenance professionals. The EXP4000 has the means to monitor and effectively troubleshoot this increasingly popular motor drive technique. The EXP4000 displays the V/Hz relationship with respect to time. This helps with setup and commissioning, and improves the ability to troubleshoot VFD issues.
- **Efficiency**: The EXP4000 identifies poorly-performing motors with accurate assessments of operating efficiency within their current applications. This is especially valuable for motor replacement decision support.
• Transient analysis: Typically used to monitor the start-up phase of the motor, measuring and recording the voltage and current against time, plus the torque profile against time.

• Continuous monitoring: The CM4000 software allows for real-time monitoring and recording of 40 parameters, including voltage, current, frequency, torque, speed and % load. Triggers can be set on any parameter to start and stop the recording at the required levels.

While the EXP4000 can be connected directly to low voltage motors (less than 1,000VAC), medium and high voltage motors need voltage and current transformers for each phase, to allow measurement via the low voltage secondary circuits. Transformer ratios are entered into the software to calculate the true values. Manual connection can be used for both LV and HV motors, but typically requires the motor to be stopped and isolated.

An alternative to connecting leads manually in the motor control cabinet, is to use a EP1000 connection module. The EP1000 is a low voltage connection module permanently installed inside the cabinet, with less than 5 V reaching the DB25 type plug that is installed on the outer door of the motor control cabinet.

Benefits of connecting via an EP unit
• Safe electrical connection without interruption to motor operation
• Opening of motor control cabinet after installation not required for testing and safe long-term data acquisition possible
• Output voltages less than 5V peak during operation
• Purely passive device when EXP4000 is not connected

Trending
All parameters are automatically saved and trended. Trending is a vital part of any condition monitoring programme.

Reporting
Following the survey, a detailed report will be issued with recommendations for each motor.

The test data will be retained for future testing, to allow long-term trending of machine condition.

Motor current signature analysis

Motor current signature analysis (MCSA) differs from dynamic analysis since only the phase currents are measured. This test method can also be performed with the EXP4000, and can be beneficial when the motor cannot be stopped to gain access to the motor control cabinet and make connections, or there are no voltage transformers present in the panel of an HV motor. MCSA is mainly used to detect cracked and broken rotor bars, and various mechanical issues.

Dynamic analysis is always recommended where possible, since the addition of voltage measurement allows power quality assessment to be made. This is important since poor power quality can lead to insulation degradation. It also allows torque to be calculated, which plays a vital role in understanding the condition of the driven load.

Additionally, SKF also offers the following site services:
• Vibration analysis using hand-held data collectors and online systems
• Balancing
• Laser alignment
• Oil analysis
Infrared thermography

Infrared thermography is a non-invasive predictive maintenance tool used for numerous applications including the inspection of electrical switchgear and control systems, mechanical systems and process systems.

Objects radiate heat as infra-red radiation, which the human eye is unable to detect. The SKF Thermal Camera TKTI series can measure and store this information allowing a skilled operator to identify a wide range of problems.

Infrared thermography has the added advantage of being a non-invasive diagnostic tool. This means that many operational defects can be determined without altering the operation of the machine or equipment, enabling condition to be determined whilst in operation.

SKF operate the latest generation of thermographic cameras, and have specialist engineers able to provide expert services for the analysis of heat generating defects for various applications. SKF can provide a comprehensive backup service ensuring we deliver expertise and recommendations on repair modifications or root cause investigations to improve the maintenance and operation of your asset.

Remote dynamic monitoring service

As an alternative to route-based dynamic testing, SKF are also able to utilise the SKF Online Motor Analysis System NetEP. The NetEP is capable of monitoring up to 32 motors, 24 hours a day, 7 days a week, with data being sent directly to SKF for analysis.

This is particularly interesting for motors in hazardous areas, or for use on offshore installations, where travelling to site is expensive and time consuming.

Typical defects detected:
- HV and LV switchgear
- Electrical distribution boards
- Electrical control panels
- Transformers
- Mechanical wear
- Misalignment
- Vessel content levels
- Pipe work blockages
- Valve operation

TKTI SERIES DETECTS UP TO

600°C

Rotor bar damage/cracked bars displaced from the SC ring