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# MEDIUM VOLTAGE MOTOR ACCEPTANCE TESTING

*Medium voltage motors have been very well understood and studied for more than a century. While manufacturing, assembling, and testing of a motor appear simple, the reality is quite the opposite.*

Oftentimes, acceptance testing of motors is specified; however, the terminology used in testing by vendors, consultants, and operators can get intertwined and end-user expectations can be misaligned with equipment vendors' procedures and deliverables. This application edge series outlines what a factory acceptance test is, the different kinds of testing available for motors, industry standards that govern motor testing, and recommendations for the type of test to select.

## Factory acceptance testing (FAT) – definition

A factory acceptance test, commonly known as acceptance testing, is a series of tests performed by the equipment supplier. The purpose of these tests is to demonstrate to the end user that the supplier meets all the contractual agreements, which consist of the latest sets of drawings, data sheets, project specifications, and any deviations that have been approved by the end user or their representative.

It is the supplier's responsibility to perform these tests, record the test data, and issue a final test report to the equipment purchaser. These tests are usually witnessed by the end user, or their representative, at the equipment supplier's facility or a third-party test stand and are executed before the final installation at the site. In limited cases, the equipment supplier will perform the tests without anyone witnessing them.

*The testing requirements MUST be defined at the purchase-order stage of the equipment procurement cycle and NOT after.*

Figure 1 shows a typical MV motor- and VFD-driven system. In order to test this system, an end user can make a selection from up to four types of testing varying in breadth and scope as shown below. This paper will focus only on motor testing (yellow highlight).

## Types of electric motor testing

Unlike VFDs, electric motors have several widely accepted types of testing. Motor testing includes "in process" testing, and the tests may be witnessed or not depending on end-user preference. Any test may be witnessed, unwitnessed, or "observed." A witness test is one where the test stand is set up and time allotted for the test to be witnessed.

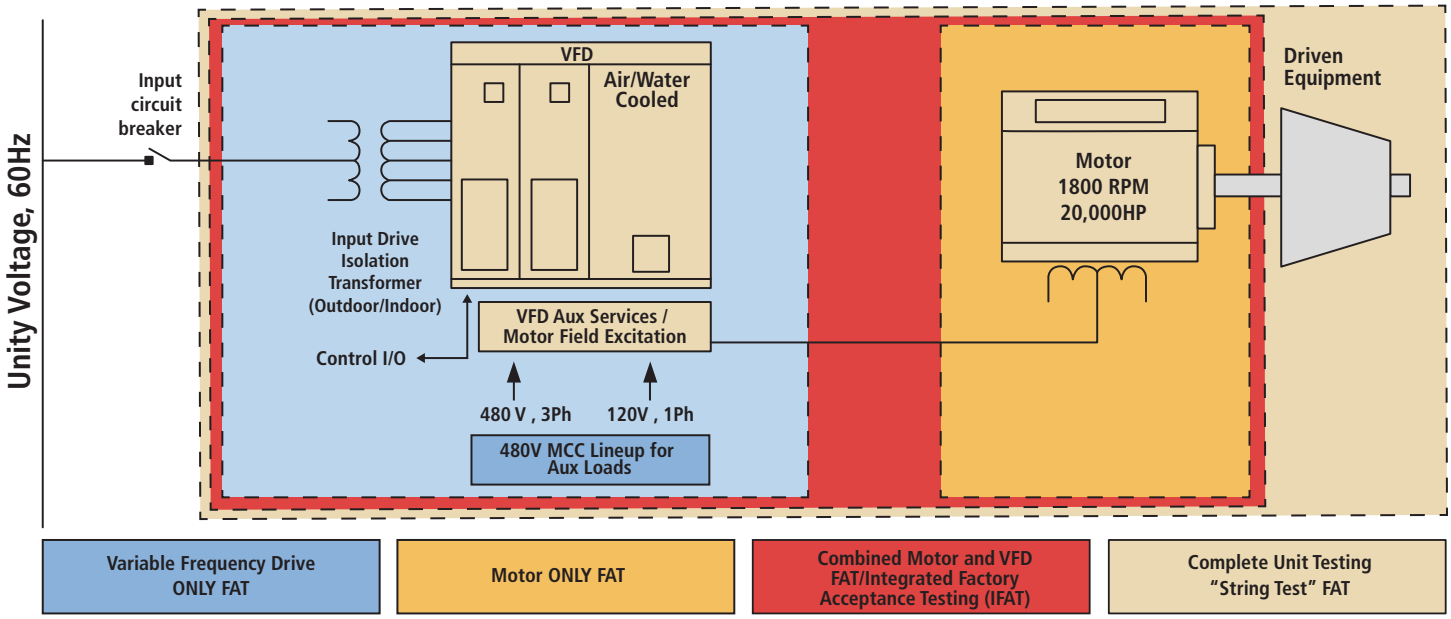


*Figure 1: MV motor and VFD driven system*

| NEMA MG-1 Sec. 20.16.2 | API 541 Sec. 6.3.2 |
|---|---|
| No Load Current | No Load Current |
| No Load Power | Locked Rotor Current By Calculation |
| No Load Speed | Ac High Pot. Test Winding and Accessories |
| High Potential Test | Insulation Resistance |
| None | Winding Resistance |
| None | Vibration |
| None | Bearing Insulation |
| None | Bearing Temperature Test |
| None | Inspection Of Oil and Oil Supply |
| None | Bearing Journal Clearance and Alignment Pre-Test (Optional) |
| None | Post-testing Inspection of Bearing and Journal Clearance |
| None | Measurement of Machine Air Gap (Optional) |
| None | Shaft Voltage and Current Measurements |

*Table 1: Comparison of routine test items and measurements by NEMA and API standards*

An observed test is performed during the course of motor production, and the purchaser's representative must be present when the factory performs the test. Note, an observed test is usually not a "hold point" in the motor manufacturing schedule. Typically, the end user will get notice of the approximate time for the test. This test can be used as an inexpensive option rather than formal witness testing; however, it is not as formal as a full witness test.

Common terms in motor testing, such as "routine" and "complete" test are defined in standards such as NEMA MG-1 [1], IEEE 112 [2], and the IEC 60034-2-1 [3]. A "routine test," as the name suggests, is normally or routinely done by the motor manufacturer on every motor whether the end user requests it or not. However, depending on which one of the foregoing standards is applied to the motor, routine test items can vary in scope. For example, routine test items defined in API 541 5th ed. [4] are significantly different from routine tests described in NEMA MG-1. Table 1 compares the test items of the two standards.

Hence, it is critical that the testing standard be defined and agreed upon before the contract for procurement is issued. This is considered a minimum test.

The "complete" test is a very common part of a FAT to be witnessed. Described in API 541 5th ed., section 6.3.5.1 outlines seven additional tests to the routine test list. Note, NEMA MG1 does not have a "complete" test definition. In some cases, if multiple identical motors are built at the same time, a routine test will be done for all motors, and one complete test will be witnessed. The complete test provides a good baseline for the motor so that 5-10 years down the line, the maintenance personnel can compare what changes time and operation have made to the motor. Table 2 compares a typical complete test to an API-specified complete test.

| Typical complete test | API 541 Sec.: 6.3.5.1 |
|---|---|
| Efficiency | Efficiency |
| Locked Rotor Current | Locked Rotor Current |
| Full-load Current and Slip | Full-load Current And Slip |
| Determine the Breakdown Torque | Determine the Breakdown Torque |
| None | Determine Speed Torque Curve |
| None | Noise Level |

*Table 2: Comparison of typical complete test and API complete test*

Special tests can be selected by the end user on a case-by-case basis. A common "in process" test that is special is the sacrificial coil test. In this test, the coils are placed in the vacuum pressure impregnation (VPI) tank at the same time as the stator and the rotor. The coils are separate from the motor coil that can be tested and cut apart to confirm the VPI was successful. The end user may require the coils to be sent to an independent laboratory for verification. The test coil reports should be available before the FAT to ensure the motor has been properly insulated during the VPI process with testing and visual inspection.

Other special tests may be done based on the specific application. It is important to understand that some special tests can have an adverse effect on the life of the motor. The API standards for motors, such as 541 and 546, are a good guide for terminology, acceptance criteria, why the test is done, and the impact that a test will have on the life of the motor. Understanding which test may be harmful to the motor should be part of the preparation. A technician may want to rerun a test for some reason, and that should be considered carefully if the test can reduce the life of the motor.

The IEEE 112 standard is a test procedure that describes motor efficiency testing. The method F is common for very large motors. It also describes most other common poly-phase motor tests. For testing large motors, NEMA MG 1 Sec. 20.16.1 specifically indicates that testing be done per IEEE 112.

IEC 60034, with all its parts, is similar to NEMA MG 1. IEC 60034-2 is an efficiency testing standard which IEEE has published a number of papers comparing the different methods. For the purposes of this article, the efficiency standard should be defined at the time of the contract, and the witnessing engineer should be familiar with the procedure and acceptance criteria.

## Recommendations for motor testing

For NEMA motors (>500 HP), every manufacturer will have a set of predefined inspection and test plans (ITPs). Regardless of the type of motor procured, the API 541 standard for induction motors and API 546 for synchronous motors is a good reference document to use to specify testing. The API standard provides a list of tests, testing procedures, acceptance criteria, and a guide in the annex for the significance of each test. If there were a "standard" test, it would be the routine test that is defined in most motor standards as the "factory" normal or routine test. These tests are much the same as for a small 1HP motor, so they should never be seen as adequate for an MV motor.

It is not common to do a full-load test of large multi-megawatt motors. Setting up a load to run long enough for the motor to rise up to full temperature can take hours or even a day, leading to a lot of wasted energy and expense. Full-load testing does not provide any real insight into a motor's quality or performance that the short-duration testing doesn't already provide.

## References


1. NEMA Standards Publication MG 1-2011, Motors and Generators, Rosslyn, VA: National Electrical Manufacturers Association, 2011.
2. IEEE Standard 112-2004: Standard test procedure for polyphase induction motors and generators.
3. IEC 60034-2-1:2014: Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)
4. API Standard 541: Form-Wound Squirrel Cage Induction Motors – 375 kW (500 HP) and Larger, 5th Edition, 2014, American Petroleum Institute.


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