**ENERGY-EFFICIENT MOTORS**

By December 19, 2010, federal regulators will require that certain motors sold in the United States exhibit specific energy-efficiency performance under the Energy Independence and Security Act (EISA) of 2007. Are you ready for this change?

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| Figure 1. Typical induction motor found in a plant. |
| **Figure 1. Typical induction motor found in a plant.** |

The pertinent portion of EISA that affects motors that plant engineers might select is the section on Electric Motor Efficiency Standards. Here’s what you can do to prepare for these changes.

**In a nutshell**

EISA reclassified general-purpose motors, 1 hp to 200 hp, as Sub-type I, and defined a new category of general-purpose motors as Sub-type II. Sub-type II motors are similar to Sub-type I motors, except they’re configured as:

* U-Frame motors
* Design C motors
* Close-coupled pump motors
* Footless motors
* Vertical solid-shaft normal-thrust motors
* Eight-pole motors
* Poly-phase motors using less than 600 volts

Sub-type II motors between 1 hp and 200 hp manufactured alone or as part of another piece of equipment are required to have a nominal full-load efficiency not less than as defined in NEMA MG-1 (2006), Table 12-11. For this same 1 hp to 200 hp range, Sub-type I motors will have nominal full-load efficiencies that meet the levels defined in NEMA MG-1 (2006), Table 12-12. The efficiencies in Table 12-12 are greater than in Table 12-11 by as much as three percentage points. Also, for the first time, the efficiency of motors between 200 hp and 500 hp is required to conform to NEMA MG-1, Table 12-11 (Table 1).

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|  | 3600 rpm | | | 1800 rpm | | | 1200 rpm | | | 900 rpm | |
| hp | Table 12-12 | IEEE 841 | Table 12-11 | Table 12-12 | IEEE 841 | Table 12-11 | Table 12-12 | IEEE 841 | Table 12-11 | IEEE 841 | Table 12-11 |
| 1 | 77.0 | 77.0 | 75.5 | 85.5 | 84.0 | 82.5 | 82.5 | 81.5 | 80.0 | 75.5 | 74.0 |
| 1.5 | 84.0 | 84.0 | 82.5 | 86.5 | 85.5 | 84.0 | 87.5 | 86.5 | 85.5 | 78.5 | 77.0 |
| 2 | 85.5 | 85.5 | 84.0 | 86.5 | 85.5 | 84.0 | 88.5 | 87.5 | 86.5 | 84.0 | 82.5 |
| 3 | 86.5 | 86.5 | 85.5 | 89.5 | 88.5 | 87.5 | 89.5 | 88.5 | 87.5 | 85.5 | 84.0 |
| 5 | 88.5 | 88.5 | 87.5 | 89.5 | 88.5 | 87.5 | 89.5 | 88.5 | 87.5 | 86.5 | 85.5 |
| 7.5 | 89.5 | 89.5 | 88.5 | 91.7 | 90.2 | 89.5 | 91.0 | 90.2 | 89.5 | 86.5 | 85.5 |
| 10 | 90.2 | 90.2 | 89.5 | 91.7 | 90.2 | 89.5 | 91.0 | 90.2 | 89.5 | 89.5 | 88.5 |
| 15 | 91.0 | 91.0 | 90.2 | 92.4 | 91.7 | 91.0 | 91.7 | 91.0 | 90.2 | 89.5 | 88.5 |
| 20 | 91.0 | 91.0 | 90.2 | 93.0 | 91.7 | 91.0 | 91.7 | 91.0 | 90.2 | 90.2 | 89.5 |
| 25 | 91.7 | 91.7 | 91.0 | 93.6 | 93.0 | 92.4 | 93.0 | 92.4 | 91.7 | 90.2 | 89.5 |
| 30 | 91.7 | 91.7 | 91.0 | 93.6 | 93.0 | 92.4 | 93.0 | 92.4 | 91.7 | 91.7 | 91.0 |
| 40 | 92.4 | 92.4 | 91.7 | 94.1 | 93.6 | 93.0 | 94.1 | 93.6 | 93.0 | 91.7 | 91.0 |
| 50 | 93.0 | 93.0 | 92.4 | 94.5 | 93.6 | 93.0 | 94.1 | 93.6 | 93.0 | 92.4 | 91.7 |
| 60 | 93.6 | 93.6 | 93.0 | 95.0 | 94.1 | 93.6 | 94.5 | 94.1 | 93.6 | 92.4 | 91.7 |
| 75 | 93.6 | 93.6 | 93.0 | 95.4 | 94.5 | 94.1 | 94.5 | 94.1 | 93.6 | 93.6 | 93.0 |
| 100 | 94.1 | 94.1 | 93.6 | 95.4 | 95.0 | 94.5 | 95.0 | 94.5 | 94.1 | 93.6 | 93.0 |
| 125 | 95.0 | 95.0 | 94.5 | 95.4 | 95.0 | 94.5 | 95.0 | 94.5 | 94.1 | 94.1 | 93.6 |
| 150 | 95.0 | 95.0 | 94.5 | 95.8 | 95.4 | 95.0 | 95.8 | 95.4 | 95.0 | 94.1 | 93.6 |
| 200 | 95.4 | 95.4 | 95.0 | 96.2 | 95.4 | 95.0 | 95.8 | 95.4 | 95.0 | 95.5 | 94.1 |
| 250 | 95.8 | 95.4 | 95.4 | 96.2 | 95.0 | 95.0 | 95.8 | 95.0 | 95.0 | 94.5 | 94.5 |
| 300 | 95.8 | 95.4 | 95.4 | 96.2 | 95.4 | 95.4 | 95.8 | 95.0 | 95.0 | — | — |
| 350 | 95.8 | 95.4 | 95.4 | 96.2 | 95.4 | 95.4 | 95.8 | 95.0 | 95.0 | — | — |
| 400 | 95.8 | 95.4 | 95.4 | 96.2 | 95.4 | 95.4 | 95.8 | — | — | — | — |
| 450 | 95.8 | 95.4 | 95.4 | 96.2 | 95.4 | 95.4 | 95.8 | — | — | — | — |
| 500 | 95.8 | 95.4 | 95.4 | 96.2 | 95.4 | 95.8 | 95.8 | — | — | — | — |
| **Adapted from NEMA MG1-2003 and IEEE Std. 841 by James Rooks** | | | | | | | | | | | |

**Moving toward compliance**

What does EISA mean for motor users? First of all, it raises the bar to NEMA premium efficiency levels. Plant professionals will have to specify premium-efficiency motors. The selection of more efficient motors actually can help keep your production costs competitive by reducing your motor energy costs.

Secondly, the new motors should be capable of operating in existing plant equipment without involving machine alterations. This means the equipment design must be reviewed in conjunction with the new motor specifications.

**Specifying new motors**

Plant engineers sometimes use specifications to purchase electric motors. But, without verifying, you have no assurance a motor meets your specifications. Verification can involve witness testing in the manufacturer’s facility or in an independent laboratory. Plants that buy motors in large quantities typically opt for unbiased, independent testing.

“The new motors should be capable of operating in existing plant equipment without involving machine alterations.”

*- Emmanuel Agamloh*

We recommend a motor build and inspection analysis (MBIA), a tear-down analysis to inspect motor components for quality. If quality is poor, there’s no benefit in proceeding further. After MBIA, the sample should be subjected to several tests. [Click here to view details of the recommended steps to qualify a motor](http://www.advancedenergy.org/motors_and_drives/consulting/services_for_OEMs.html).

With EISA in effect, although a motor has passed the qualifying tests, it still must conform to the law. Therefore, the first step is to ensure the motor is EISA-compliant. Although the burden of proof isn’t on users, they must be proactive to ensure the motor manufacturer is compliant. A manufacturer that has demonstrated compliance should have a unique compliance certificate number (CC#) issued by the United States Department of Energy (DOE).

**Key compliance steps**

The motor rules for EISA are part of the DOE backlog and the final rules are scheduled to be published in December, 2012. We can speculate that the basic formalities under the existing law wouldn’t change significantly.

Under existing law, manufacturers must prove their motors are compliant. One way is to test a required number of motor samples in a laboratory accredited under the National Voluntary Laboratory Accreditation Program (NVLAP), another is to use a third-party organization to certify. In either case, application must be filed with the DOE, listing the covered motors and performance data proving compliance.

Efficiency is determined by testing a minimum of five samples from five so-called basic models in a NVLAP lab to verify the Alternate Efficiency Determination Model (AEDM). AEDMs are analytical calculations and computer models that predict motor efficiency (or losses). DOE’s objective is to reduce the burden of testing on manufacturers. Therefore, it allows them to use mathematical calculations or models to predict the efficiency of the motors they produce and use these predicted efficiencies to certify the motors. However, before using those mathematical models, they must be substantiated through actual tests. In other words, they must test the 25 motors to prove that the mathematical model predicts well and then use the mathematical model to predict efficiency for the rest of the “basic models” listed on the application. Without AEDM, the basic models listed on the application will require lab tests, running into hundreds of units. Motors of the same rating with essentially identical electrical characteristics and the same efficiency are considered to be the same basic model.

**Repair/replace decisions**

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| Figure 2. Ultra-high-efficiency permanent-magnet motors feature a permanent magnet rotor (top), a stator, and an electronic module (bottom). |
| **Figure 2. Ultra-high-efficiency permanent-magnet motors feature a permanent magnet rotor (top), a stator and an electronic module (bottom).** |

How will EISA influence motor repair-replace decisions? Before EISA ruled on it, an efficiency gap existed between energy-efficient and premium-efficient motors. When a motor fails, engineers decide either to replace it with a premium unit or a standard product. After EISA, new motors between 1 hp and 200 hp will be premium-efficiency, making a premium motor the only choice for replacement, although that doesn’t rule out repairs. Now, when a premium motor fails, the decision might be tilted towards repair.

Because of replacement cost, a large number of failed motors are repaired. As part of marketing efforts, NEMA supported legislation aimed at increased usage of premium-efficiency motors. The stalled “crush for credit” bill was a rebate program for the purchase of NEMA Premium motors to retire older motors, similar to the cash for clunkers program for automobiles. Several utilities already offer rebates to encourage the use of premium motors.

Under EISA, utilities might no longer rebate the purchase of premium motors because these motors would be the norm. The only factor that might keep the rebates alive longer is the stock of old motors remaining at the end of 2010. They might have to be sold for fire sale amounts or might remain in warehouses forever if customers are instantly tuned to premium-efficiency units. The utility rebates might be channeled towards variable-frequency drives (VFDs) or more efficient motor technologies.

Ultra-high efficiency designs such as permanent-magnet and copper-rotor motors remain prospective candidates for utility rebates. Generally, permanent-magnet motors (Figure 2) have higher efficiency than induction motors. At least one manufacturer has plans to develop permanent-magnet synchronous motors for many industrial applications. It’s more likely these offerings would cater to large compressors, commercial refrigeration and air-conditioning equipment. Already, electronically-commutated motors, a type of permanent-magnet motor, (Figure 2) are proposed as drop-in replacements for some single-phase induction motors. It’s expected that utility programs will consider permanent-magnet motors for future rebate programs.

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Another post-EISA rebate technology is the copper-rotor motor (Figure 3). Traditionally, the rotors in small-to-medium horsepower induction motor are made of aluminum die-cast squirrel cages. This technology is old, reliable and time tested. Although the conductivity of copper is greater than for aluminum and could lead to reduced rotor losses, copper die-casting has been a big hurdle because of the metal’s high melting point. Research at the Copper Development Association has improved the copper die-casting process. Copper rotor motors that have efficiencies greater than NEMA premium are available. However, these motors are only currently offered with 20 hp or less.

**Motor repair quality**

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| Figure 3. A die-cast copper rotor can boost efficiency, but they are available only in smaller motors. |
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In the EISA era, there will be increased tendency to repair failed premium-efficiency motors. The justification to repair is contingent upon achieving pre-failure efficiency. Contrary to widespread perceptions, motor repair doesn’t always degrade efficiency. We’ve seen evidence of quality repairs through a program that certifies motor shops. Under the Proven Efficiency Verification (PEV) program, shops are audited on-site and brought to conformance with best practices. After the audit, sample motors are tested, damaged and sent to these shops for repairs. The before-and-after test results are compared and must be within a tolerance before a repair shop receives accreditation. Furthermore, to ensure that quality hasn’t drifted, the before-and-after tests are repeated each year for the next four years before another on-site audit is done.

In September, 2008, Bonneville Power Administration (BPA) contracted with a company to run the [Green Motors Initiative](http://www.greenmotors.org). Under this initiative, repair shops commit to repair motors in accordance with specified standards and are given a rebate incentive, split evenly between the motor repair company and its customer. Various utilities support the Green Motors Initiative. The fact that this program is now considered an important energy-efficiency measure demonstrates the value of the PEV program. The PEV goes beyond a declaration of intent to repair motors to specified best practice standard — it provides motor repair shops the opportunity to prove, through testing, that it’s actually meeting energy-efficiency goals.

**Variable-frequency drives**

The benefit of using VFDs for certain applications when speed control is important is well known. But market penetration of VFDs is still low. After EISA, we expect that attention will turn to promoting the use of VFDs for the covered motors.

Currently, there’s greater standards-development activity in this area. The Air-Conditioning, Heating and Refrigeration Institute (AHRI) is developing standards for testing motor-VFD systems. IEEE and CSA standards also are expected. NEMA might adopt similar standards that others develop. The International Electrotechnical Commission (IEC) recently published a standard for testing the efficiency of motor–VFD systems. Although the United States is ahead of Europe in prescribing tougher efficiency standards, the Europeans are the first to include motor-VFD systems as options to meet its standards. By 2015, the minimum-efficiency standards in Europe would be IE3 motors or IE2 motors plus a VFD. Having a test standard in place is a good call.

**Single-phase motors**

In addition to EISA, the [DOE is pursuing a separate process to establish minimum efficiency standards for small motors in two-digit frame sizes 42, 48 and 56](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/sem_finalrule_notice.pdf.). The final rule was released in February 2010.

The small-motor rules would become effective in 2015. Given that the discussions concerning regulation of small motors has been lingering for years, many might find this 2015 compliance date too far in the future. But there’s work to do in preparation. Manufacturers might have to redesign their products and assembly lines and IEEE will have to complete the revision of its 114 test standard required for verifications. While everyone is waiting for 2015, brushless DC motors might be in position to replace the traditional capacitor-start motors for many applications.

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