Motor Circuit Analysis Standards

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Over the past several years, there has been discussion about whether Institute of Electrical and Electronics Engineers, Inc. (IEEE) standards cover Motor Circuit Analysis (MCA) techniques and methods. The answer is simple, yes, they do. In this article, we shall discuss some of the issues related to the standards development process and the standards that are related to ALL-TEST technology (other off-line testers do not meet all of these standards).

The IEEE standards process can be quite interesting, if not a little cumbersome. It takes years, in many cases, to develop, if not just modify or update, a standard. Following is a brief outline of the process. The proposed standard must meet certain criteria and have peer acceptance, prior to setting up a working group. The working group must be selected and have regular update meetings, with a chair to preside over the process. All members of the group must agree with the standard, including grammatical details. Once past this point, the standard is issued to a selected group of engineers with similar interests and they vote on it. A single negative vote puts the standard back into committee. Once it has gone through a number of iterations, the standard is collected back at IEEE headquarters and issued as a standard.

The positive side to this process is that there is a method to ensure that 'junk' standards are not issues. The negative side is that a special interest group, company or individual can hold up a standard until it is out of issue, or until the committee agrees to keep or reject the particular subject. This can become an issue if, for instance, a manufacturer of a particular type of testing is on a committee and a re-issue of a standard would eliminate one of their selling or design points from an existing standard. They can stall the process until a compromise occurs, in some cases just before a standard would be rejected as a result of a maximum time period. It is not unusual for a company or a test group to spend years getting up-to-date test methodology into standards, either as new or added to existing standards. It is also important to note that most IEEE standards do not give absolute pass/fail values – those are normally issued as 'Guidelines' or 'Recommended Practices,' and contain words such as 'may' or 'should.'

It was interesting to note that the standards which cover MCA were found outside of standard motor testing standards, during a standard proposal search. Keeping in mind that an electric motor is a transformer with a rotating secondary (stator is the primary winding, rotor is the secondary winding), the particular test methods were found in the transformer test standards – including some ideas that we thought we had come up with independently.

IEEE Standard 43-2000 was reissued in May of 2000. It is the "Recommended Practice for Testing Insulation Resistance of Rotating Machinery" and covers the recommended limits for insulation testing. An interesting point to note is that the new issue downplays

Polarization Index and Dielectric Absorption tests, noting that to perform such tests on insulation systems reading over 5,000 MegOhms is pointless (the wording is not far off). The standard was almost re-written in the form of a paper, stating that new insulation systems polarize much more quickly than pre-1970 insulation systems. As a result of these changes, there are new limits to insulation resistance tests:

- 1 MegOhm + 1 MegOhm/1000 Volt rating of equipment for insulation systems prior to 1970
- 5 MegOhms for random wound motors under 600 Volts
- 100 MegOhms for form wound motors, motors over 600 Volts and armatures

IEEE Standard 56-1977, the "IEEE Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery." This standard provides guidelines for testing and inspection of insulation systems on motors. Insulation test methods follow the testing methods used by MCA devices for insulation to ground evaluation.

IEEE Standard 118-1978 is the "IEEE Standard Test Code for Resistance Measurements." The ALL-TEST IV PRO meets the general requirement (ie: similar to the Wheatstone Bridge method of testing).

IEEE Standard 120-1989 is the IEEE Master Test Guide for Electrical Instruments in Power Circuits. This standard discusses and outlines a number of issues important to MCA, including: Section 5.6 – Bridge methods used for data collection; Section 7.4.2 – Alternating current sources used for evaluation; and, Section 8.1.5 – Data Analysis. The ALL-TEST MCA equipment meets each of these requirements.

Now comes the interesting part. The IEEE transformer standards:

IEEE Standard 388-1992 is the "IEEE Standard for Transformers and Inductors in Electronic Power Conversion Equipment." Outlined in Section 5 are the electrical tests: Section 5.2 – Inductance and Impedance unbalance testing. Describes how to test and evaluate; Section 5.4.2 was interesting and supported our statements from the past concerning repeated high voltage testing for preventive and predictive maintenance – "Repeated electrical strength testing [ie: Hi-Pot and Surge Testing]. Repeated testing may impair the strength of the transformer or insulation system."; and, Section 5.6.1 discusses the inductive bridge method of measurement for phase balance. The presentation of Standard 388 allows itself to cover other equipment including electric motors and coils.

IEEE Standard 389-1996 is the "IEEE Recommended Practice for Testing Electronics Transformers and Inductors." This is one of the more important standards relating to MCA. Table 1 of the standard provides the recommended tests and specifications for transformer and inductor groups. It also covers impedance and reactance limits as well as conductor resistances. Then, discussed under General Test Methods – Surge Testing - "The test itself is destructive." Section 6 discusses simple DC resistance tests and limitations. Sections 8 through 11 cover the meat of MCA testing using ALL-TEST style methods: Section 8.1.1 – calculating winding ratios with inductance. This section was interesting as we had issued a test procedure for transformer testing which required the user to short and ground all of the leads opposite of the side being tested. Standard 389 specifically outlines the same procedure; Section 8.1.2 – Transformation ratio with by impedance measurements; Section 8.3 – Impedance unbalance methods and limits; Section 8.4 – Phase balance tests and limits; Section 10 – Inductance measurements by impedance bridge method; and, the truly interesting find – Section 11.1 – The transformer frequency response, which outlines test methods that validate the ALL-TEST patented Current /Frequency (I/F) test method.

As shown and described above, MCA testing is covered by IEEE standards. Now, are there other standards and references? Absolutely!

ANSI/EASA Standard AR100-1998

Motor repair shops will sometimes pose the question: Which of our industry standards cover Motor Circuit Analysis? Well, other than the IEEE standards listed above, the (fairly) newly released ANSI/EASA Standard AR100-1998 covers details of MCA testing.

While most motor repair shops use surge testing to evaluate motor windings, as also evident in the standard, enough shops use alternative test methods to warrant discussion in the ANSI/EASA standard. These can be found in Section 4, under 4.2.6 "Turn-to-Turn Test" and 4.3 "Recommended Winding Tests." MCA is liberally described as "phase balance" testing, resistance testing and insulation to ground testing.

Book References for Motor Circuit Analysis

There is nothing magic about Motor Circuit Analysis. The basic principles predate the invention of alternating current motors, covered by basic electrical laws and simple electrical bridges (method of measurement). The key has always been data interpretation and setting test limits.

The following books discuss the theory of MCA and provide insights into the practical applications of MCA for motor and transformer testing:

"Motor Circuit Analysis: Theory, Application and Energy Analysis," by Dr. Howard W. Penrose, Ph.D., published by SUCCESS by DESIGN in July, 2001, (ISBN: 0-9712450-0-2), is the first book in the technology. It describes everything from basic electricity, to motor theory (for all types of AC and DC motors and transformers), to reliability, testing, building a maintenance program, cost justification of a maintenance program, the energy impact of maintenance, case studies, and contains a CD ROM with supporting PowerPoint presentations and software. The book was written to be understood by anyone involved in maintenance or maintenance management in plain English.

“Standard Handbook for Electrical Engineers: Fourteenth Edition,” edited by Donald Fink and Wayne Beaty, McGraw-Hill, 2000. The book discusses electric motor phase unbalance in both impedance and voltage. “Inherent in unbalanced faults is the fact that negative-sequence current is present. Flux associated with negative sequence rotates in a direction opposite to rotor rotation. This causes appreciable current flow in rotor structural parts that are not designed for such current, and excessive heating occurs.” Which can be demonstrated in cases of increased heating in motors with excessive impedance unbalance (when corrected for rotor position). This is an excellent reference book, but requires some background to read and understand the materials.

Other great references include:

“Electric Machines: Steady-State Theory and Dynamic Performance: Second Edition,” by Mulukutla Sarma, PWS Publishing Company, 1996. Covers design and testing of AC/DC motors and transformers.

“Troubleshooting Electric Motors: Second Edition,” by Glen Mazur and Thomas Proctor, ATP Publishing, 1997. Is an excellent book on motor theory and troubleshooting. There are some interesting facts included. The book does not cover MCA directly, but covers the materials supporting MCA.

Conclusion:

There is truly very little mystery to motor circuit testing and analysis. Industry standards, textbooks, and articles have covered the subject for decades. In particular, there are IEEE, EASA and other standards that cover the testing provided by ALL-TEST instruments and that govern data gathering and interpretation. There are also practical guides and textbooks that provide details on the subject, of which our book, “Motor Circuit Analysis,” ties all of the information together.