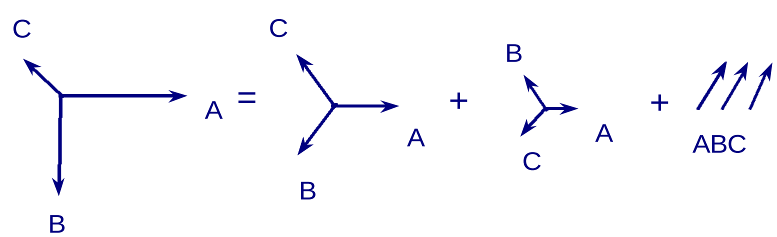
It Isn't Easy Being Green
Richard P. Bingham, Dranetz-BMI

Kermit, the Frog, was one of the many Muppet creations of the late Jim Henson. Kermit's words are becoming the lament for electric motors, as today's electric environment is making it tough to be a motor. It isn't easy being a motor.

A recent EPRI study indicated that in 1985, 25% of the loads were "electronic", which can be translated as non-linear, harmonic-generating types of loads. In 1993, that number had increased to 50%, and by the year 2000 (provided all of the doomsday predictions with the Y2K software problems don't come true), 65% of the load will be non-linear. The result is an increase in current harmonics, which in turn results in the propagation of harmonic-based voltage distortion.

Some of the losses in an electric motor are frequency dependent. As the frequency of the voltage and current goes up, the losses go up. In fact, some of the losses increase as the square of the harmonic number, such as eddy current losses. These additional losses result in additional heat in the motor, which affects the aging of the motor. This is the reason for the transformer derating factor, suggesting what the maximum load levels that are allowable for the transformer based on the present level of current harmonics. Some manufacturers produce K-factor transformer so such applications. Similar types of deratings are needed for motors.

The voltage and current in three phase systems can be represented by a set of vectors or phasors referred to as the sequencing components. An example of such is represented for discussion purposes in the below example (that means the picture drawn is not mathematically accurate).



Three Phase Vectors equals the sum of the Positive Sequence + the Negative Sequence + the Zero Sequence vectors.

In many systems, the harmonic components can be associated with the different sequencing vectors. The table below shows which type of sequencing component that each harmonic is.

HARMONIC	1ST FUND	2ND	3RD	4TH	5TH	6TH	7TH	etc
SEQUENCE	+	-	0	+	-	0	+	

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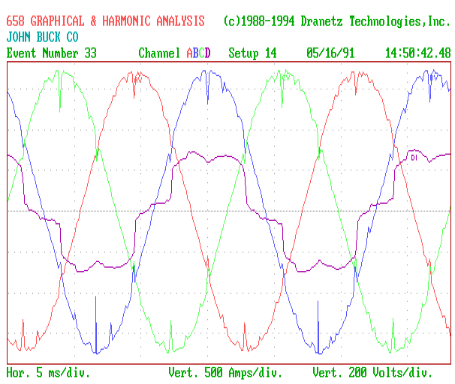
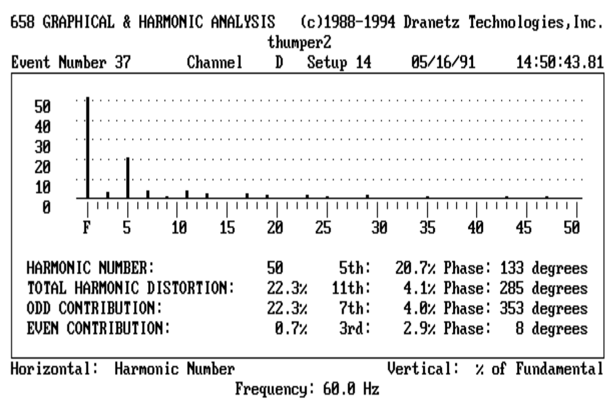
The positive sequence values are those that could cause the motor to rotate in the same direction as the fundamental frequency (60Hz in North America), whereas the negative sequencing components would try to turn the motor in the opposite direction. The net result is heat in the motor, which again causes premature aging of the motor. The EPRI Distribution Power Quality survey, conducted on the distribution voltage system of 100 utilities throughout the United States during the mid 1990's found that the most dominate harmonic out there on those systems is the 5th harmonic, which is referred to as a negative sequencing component. Life gets tougher for the motor.

In addition to these undesirable effects on motors, many motors are being sold today powered from an electronic power converter. These systems are referred to as adjustable speed drives (ASDs) or variable frequency drives (VFDs). These are sold as energy efficient alternatives to powering the motor directly from the electric utility power. They take the AC voltage, convert it to DC voltage, and then recreate an AC voltage at a frequency necessary to provide the power for the present load. For example, in an HVAC system, it may not be necessary to have the fans running at full speed all the time. Instead, the speed can be made dependent on the amount of air that needs to be moved, which is dependent on the temperature desired.

The power converter section of ASDs is usually made of diodes or SCRs that are used to rectify the AC into DC. A three phase, full wave rectifier is referred to as a six pulse or pole converter. Such rectification results in non-linear harmonic currents, as the conduction of the current does not take place throughout the complete 60Hz cycle. A handy formula for determining the harmonics from such as system is the harmonic numbers, h, are equal to the number of poles (p) multiplied by integers (n) plus or minus 1. Hence, h = n * p +/- 1, where n= 1, 2, 3, 4,.....

The six pulse converter will have harmonic currents of the 5th, 7th, 11th, 13th, 17th, 19th, and so on. Since these type of converters are presently the most popular for use in ASDs, we can see that the most dominate harmonic is the 5th (as the EPRI DPQ survey found), and again, this is a negative sequence value. Harmonic currents are also being attributed to current flowing through the shafts in motors with non-insulated shafts. The result is bearing damage referred to as fluting. Life keeps getting tougher for the motor.





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Many of these converters have an output that is not very sinusoidal, especially pulse width modulated (PWM) drives. These devices put out a series of pulses that have high frequency components in them. The high frequencies are beginning to draw attention to themselves as the possible source for premature winding failures in the first several turns of the motor windings. Some motors are now being wound with special wiring to help prevent this problem. And life just keeps getting tougher...

Not to be forgotten is the effect of voltage unbalance. Even a small unbalance can cause motor overheating. Voltage unbalance can result from unequal loading, unequal source impedance, or an unequal source voltage. It is quite typical in today's electrical environment to have a 2-3% voltage unbalance. The NEMA MG1 / ANSI C112 says a 3% voltage unbalance should results in a derating of the motor by 10%. So now we are derating the motor because of harmonic losses, negative sequence values, and voltage unbalance.

And finally, the push for profitability has inflicted cut backs in operating and maintenance budgets along with reducing of work force. The postponing of the normally schedule preventative maintenance of the motor can result in shortening of the life of the motor as well as having small problems going undetected until a catastrophic failure of the motor occurs. This can be a very expensive proposition if the motor used is in a critical process.

Yes, Kermit, it isn't easy being green, and today, it isn't easy being a motor.

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