

VIBRATION OF AC INDUCTION ELECTRIC MOTORS & GENERATORS

By Tom Irvine
Email: tomirvine@aol.com

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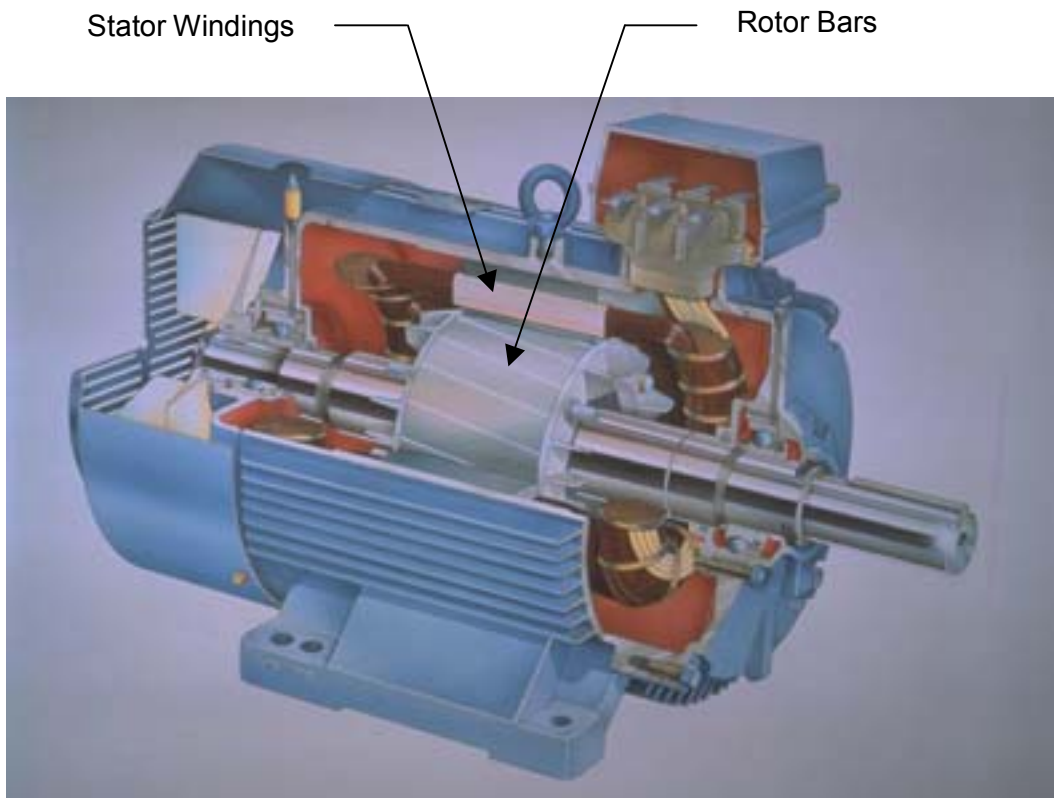


Figure 1. AC Induction Motor (Image Courtesy of IEEE)

Introduction

An AC induction motor converts electrical energy into mechanical motion. Conversely, a generator converts mechanical motion into electrical energy. A motor and a generator may have similar designs. In some cases, a motor may also be used as a generator.

The motor in Figure 1 is a squirrel-cage induction motor.

A squirrel-cage motor consists of an outside stationary stator which has coils. The coils are supplied with three phase AC current to produce a rotating magnetic field. The stator magnetic field causes a current to flow in the rotor bars. The current in the rotor creates a second magnetic field which has opposite polarity relative to the stator field. The resulting interaction of magnetic fields produces the torque which causes the rotor to turn.

The rotor laminations are skewed to provide smoother torque

The rotor does not quite keep up with the rotating magnetic field of the stator, however. It falls behind or slips as the field rotates. Motor slip is necessary for so that the shaft can supply useful torque.

Another type of AC induction motor is the permanent synchronous motor which has permanent magnets on the rotor.

Potential Forcing Functions

There are two particular forcing functions in AC motors and generator, which produce noise and vibration. Note that energy from the forcing function may be amplified by structural resonances.

Magnetic Noise

This first source is magnetic noise. Magnetic noise is caused by periodic forces which are almost exclusively in the air gap between the stator and the rotor. There is a varying force proportional to the square of the flux density at every point on the air-gap surfaces.

The sum of the tangential components of this force is proportional to the total torque, which produces the useful work of the motor. Tangential force pulsations produce a torsional vibration of the stator which can cause the stator frame to rock in its mountings. This torsional vibration is a major source of structure-borne vibrations.

Furthermore, the radial components of the magnetic force do not contribute useful work but serve only to produce noise. The forces are called parasitic forces.

The magnetic forces are due to many mechanical and electromagnetic properties of the stator-rotor assembly. They include:

1. The number of rotor and stator slots and the difference between these two numbers.
2. The characteristics of the fundamental flux field for which the motor is designed.
3. Permeance variations in the air gap caused by stator slots, rotor slots, slot pattern, saturation, and air gap eccentricities.
4. The manner in which the coils of the pole windings are formed.
5. The radial length of the air gap.

In addition, non-uniformities, eccentricities, and nonlinearities produce “dissymmetry harmonic forces.”

Force Waves

The rotor and stator may be distorted by force waves. This can occur in two ways:

1. Two-node bending motion of the rotor
2. A rotating four-node elliptical distortion of the stator

The two-node rotor motion can be caused by running the rotor at its critical speed. This is the speed at which the bending mode of the rotor is excited.

Other Concerns

The following sources may produce additional noise:

1. Unbalanced line currents in a three-phase power
2. Rotor imbalance, shaft misalignment, and bearing problems
3. Gear meshing in the transmission
4. Magnetostriction in the stator laminations

Example

An accelerometer measurement was taken on an AC generator housing. The resulting Fourier transform is shown in Figure 2.

Reference

1. C. Harris, editor; Handbook of Noise Control, McGraw-Hill, New York, 1957. See R. Fehr & F. Muster, Chapter 30, Electric Motor and Generator Noise.

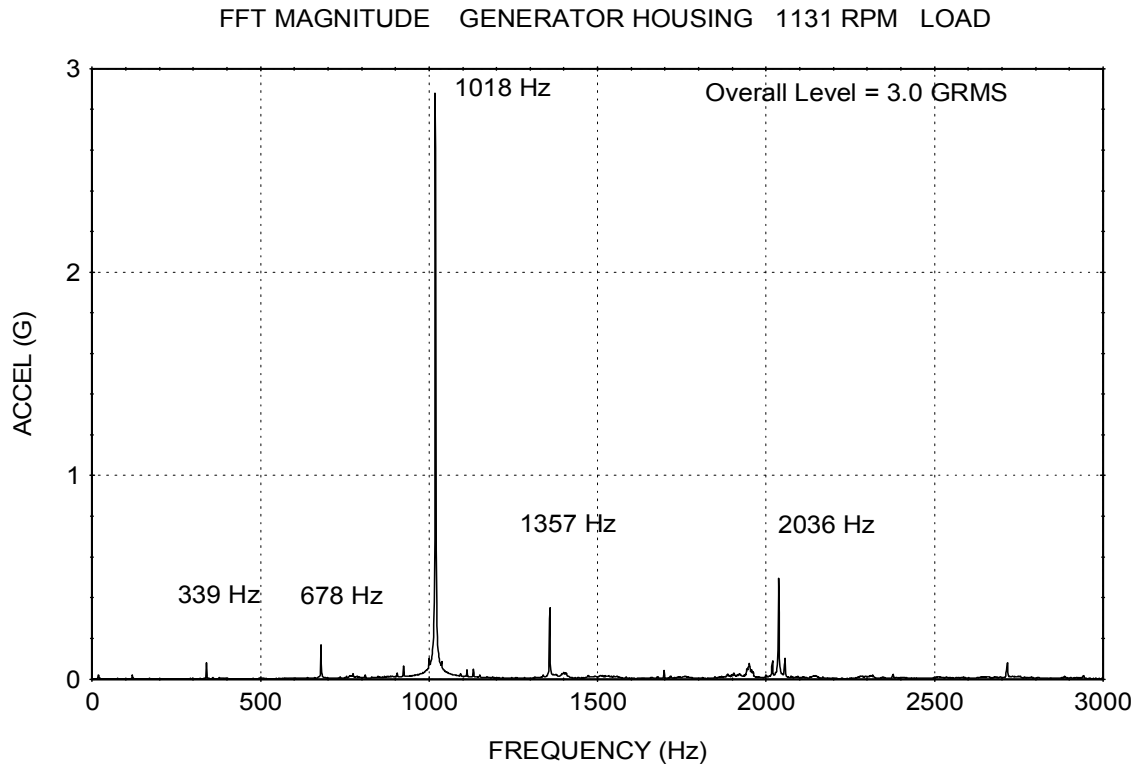


Figure 2.

Table 1. Frequency Reference				
RPM	(Hz)	x6 (Hz)	x18 (Hz)	x 54 (Hz)
1131	18.85	113.1	339	1018

Note that the generator had 6 diodes, 18 magnets, and 54 stator positions.

Table 2. Frequency Identification	
Freq (Hz)	Source
339	Number of magnets x rotor speed
678	2 x Number of magnets x rotor speed
1018	Number of stators x rotor speed
1357	(Sum of magnets & stators) x rotor speed
2036	2 x Number of stators x rotor speed