

# APPLICATION

## NOTE #114

# Testing Electric Motor Driven Equipment

## Introduction

California Instruments precision power sources can be used to test electric motor/drive systems. These systems may include either AC or DC motor types, sometimes combined with electronic controls. Motors are typically used to drive pumps, blowers, fans, conveyors, elevators, printing presses, robotics equipment, NC machinery, and a variety of appliances such as vacuum cleaners, mixers, refrigerators etc. This application note describes the features and capabilities of various California Instruments power sources, and how they may be used to test products that rely on electric motors.



## Motor types and applications

Electric motors can be divided into categories by application, design type, or even by horsepower. DC motors are commonly found in applications where speed control is required, or where only battery power is available. High power DC motors

are used in many public transportation systems such as subways. Brushless DC motors, either permanent magnet or Switched Reluctance (SR) types are found in appliances such as vacuum cleaners. Many home appliances are driven by single phase AC motors.

Three phase induction motors are the industrial “workhorses” available in two basic types, the wound rotor and the squirrel cage motor.

Whereas variable speed applications used to be the exclusive domain of DC motors, high power solid state electronics have made variable frequency AC drives (VFD) a popular choice. These modern pulse-width modulated (PWM) variable speed drives offer energy savings in many cases where standard induction motors are used today. Those PWM-AC drives are therefore quickly finding their way into many drive systems, even those with constant speed-variable torque applications.

Irrespective of type, be it AC or DC, more than 85 % of all motors require less than 50 KVA in power, hence we are primarily concerned with products in the power range up to this level. Generally, efficiency and operating reliability are the most important characteristics of any motor driven equipment, although regulatory requirements play a critical role as well. Therefore, in addition to efficiency and reliability aspects, a number of other characteristics need to meet minimum standards.

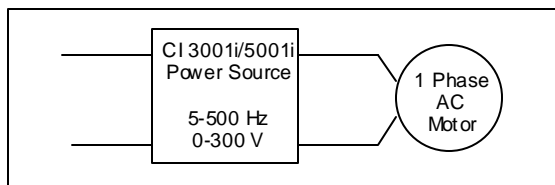


Figure 1 : Single Phase AC Motor

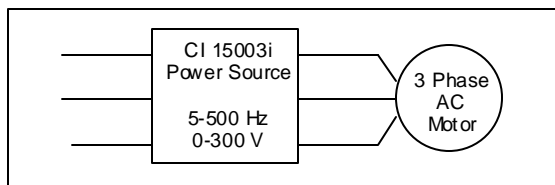


Figure 2 : Three Phase AC Motor

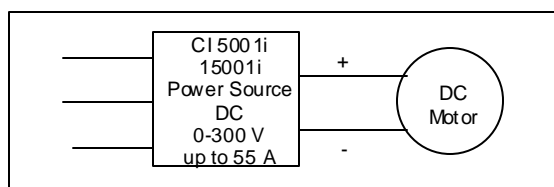


Figure 3 : DC Motor

## Motor Operating Characteristics

First and foremost, the motor/driven equipment has to perform properly in its primary function, to reliably convert electrical into mechanical energy, preferably in an efficient manner, without affecting other (electrical) equipment.

It is unacceptable if the motor or its electronic drive cause problems for other equipment which may be connected to the same line voltage. Tests therefore must include reliability and efficiency, as well as other operating aspects. Modern power sources provide the required voltages and drive frequency flexibility needed to perform testing in a consistent manner.

- **Overall efficiency and efficiency vs. load.**  
The user can read the electricity consumption directly from the power source, and thus determine input power for various conditions. For motors with AC drives, the power source can take the place of the drive, allowing the impact of different fundamental frequency and V/Hz settings on motor performance to be established quickly.
- **Power consumption and line distortion.**  
Distortion may be caused by the motor or the controller. Current harmonics, overall Power Factor, and the influence of line voltage variations may need to be determined.
- **Inrush and operating current levels.**  
The motor/driven equipment must perform as required under various load and line voltage conditions. It may be necessary to establish current/torque at full load, locked-rotor current, and the current at breakdown torque. For AC drives, it may be necessary to evaluate the start-up behavior with different current limit settings.
- **Determining system losses.**  
When evaluating overall efficiency it is necessary to establish where losses come from. This may include motor related losses such as Stator  $I^2R$  losses, Core loss, Friction, and Stray losses, using the methods described in IEEE-Std-112 \*. Test method C of this standard ( Duplicate Machines ) can be implemented using California Instruments power sources and two identical motors.
- **Emulating variable speed drives.**  
The power source may be operated as the

“ideal” variable speed drive, as frequency and voltage can be varied, and even be swept across ranges as needed (see Figure 4). This allows the system integrator to test the driven equipment under any condition. Also, the user can establish (motor) operating temperatures for low speeds, check required skip ranges, determine the required peak current levels, and even test braking and reversed rotation capabilities.

## Power Source Capabilities

Reviewing the capabilities of modern power sources will help to better understand their test capabilities. Figure 5 shows the basic architecture of a typical modern, programmable power source, such as the single phase output 3001iX, 5001iX, and 15001iX. The 15003iX provides three phase output capability, but is otherwise similar in concept.

For many fractional horsepower motors, the 3000VA output capability of the 3001iX will suffice. This source operates from a single phase line voltage, from 188 - 264 Vrms, and a frequency of 45 - 66 Hz. As follows from Figure 5, the line voltage is first converted to DC, and then inverted to the desired voltage (and frequency), using state-of-the-art power electronics.

## Variable frequency and voltage

The power sources can produce either AC or DC output voltages, in two ranges of 0 - 135 and 0 - 270 Volt. The AC voltage can be set to frequencies from 5 to 500 Hz. Current limits can be set as required, although the sources can drive high inrush currents. In fact, even the 3001iX can support peak currents up to 110 Amp. This is important when measuring locked rotor or motor inrush current. The user can program the output voltage starting angle, simulating arbitrary turn-on points in the power cycle.

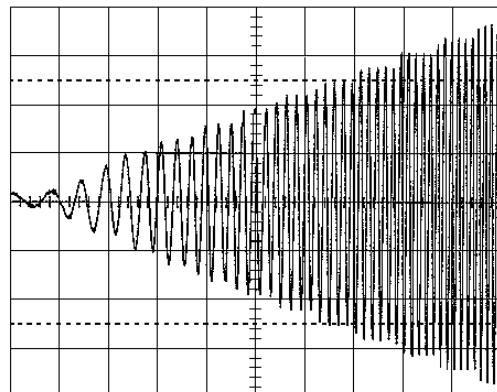


Figure 4 : Voltage-Frequency Sweep @ 4 V / Hz

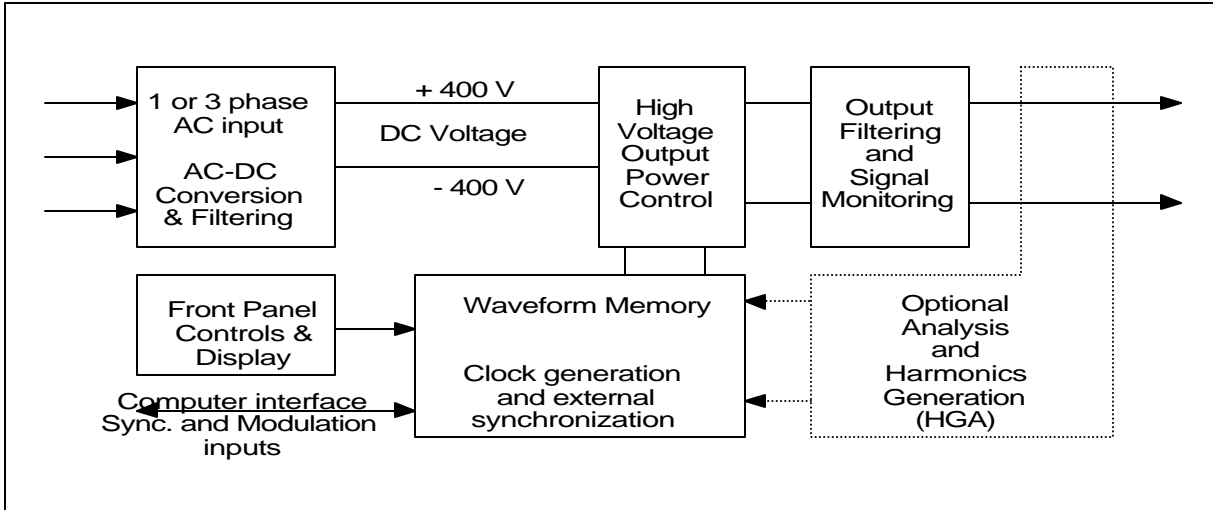


Figure 5 : Power Source Block Diagram

### Built-in measurement & analysis

With the built-in measurement capability, the user can monitor RMS as well as peak current levels, along with a number of other parameters such as power, Power Factor, voltage, and frequency. The power source can be controlled by a PC through the Graphical User Interface (GUI) software. The iX Series of AC power sources provides detailed voltage and current analysis (Figure 7).

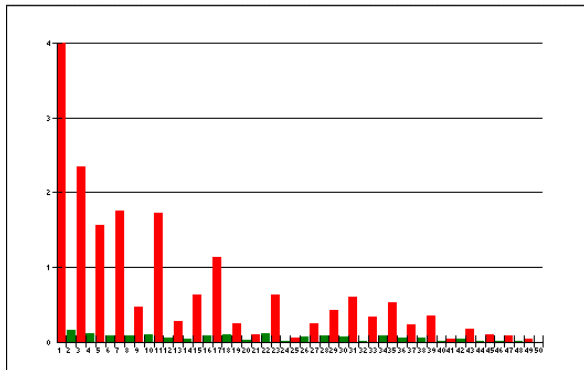


Figure 7 : Harmonic Analysis

### Line distortion simulation

As many as 32 test sequences to emulate line transients, drop-outs, power sags, etc. can be selected by the user. The power source can be programmed, using the iX Series, to perform powerful motor tests with user defined voltage harmonics (Figure 6). Harmonics may cause motor temperatures to increase. Also, mechanical problems, not detected with nice clean supply lines,

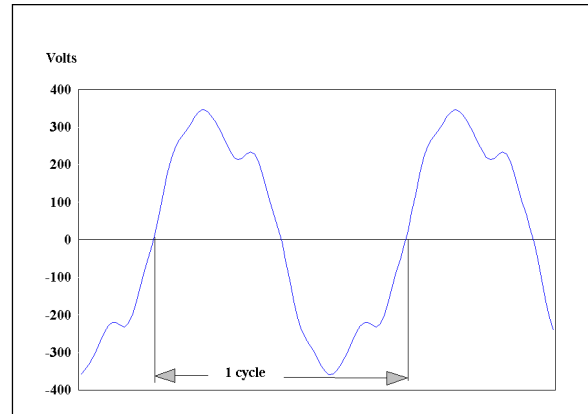


Figure 6: Harmonic voltage waveform

may show up when operating with distorted supply voltages.

### Line induced vibration/torsion transients

The 5<sup>th</sup> and 11<sup>th</sup> harmonic currents produce negative phase sequences, which in turn may excite torsional resonances. This is of particular importance for complete drive systems, with speed reduction/step-up gears, pumps, blowers, conveyors, fans etc.

Line drop-outs or voltage surges can also cause mechanical problems. New standards are going into effect, which require the manufacturer to test electrical equipment under these adverse supply line conditions. The new IEC1000-4-11 standard calls for a specific set of voltage dips, interruptions and variations, which electronic and electrical equipment

must withstand without causing danger or adverse consequences for the user. The specified voltage fluctuations are based on elaborate survey data, obtained in industrialized countries. (see California Instruments Application Note # 103 for more details),

Table 1 shows the typical number of line disturbances per year, classified by severity, that have been measured in European countries. As the table shows, voltage dips up to 30 % with a duration of 0.01 - 0.1 second occur 61 times per year. Similarly, voltage dips up to 60 %, with durations ranging from 0.1 - 3 seconds, total 49 times per year (8 + 36 + 4 + 1) hence about once per week.

Table 1 : Voltage Dips/Year in Europe

Dip in %	Duration of voltage dips (sec)			
	0.01- 0.1	0.1 - 0.5	0.5 - 1.0	1 - 3
10 - 30 %	61	66	12	6
30 - 60 %	8	36	4	1
60 - 99 %	2	17	3	2
100 %	0	12	24	5

Even more severe dips (drop-outs) occur relatively frequently.

Often the motor and motor drive equipment, when tested separately at each manufacturer's facility, perform just fine during line disturbances. Once coupled together, the combined system could still be susceptible to line disturbances. For systems controlled by an electronic drive, transient problems may be compounded for the longer duration voltage dips. Typically, the drive has the ability to "ride through" voltage dips lasting only a few cycles. Depending on load condition, longer dips may cause the drive to completely reset, and turn off the output or activate a new start-up cycle. Therefore, the complete drive system needs to be verified under various operating and supply line conditions. These supply line conditions can be simulated at will with the modern solid state power source.

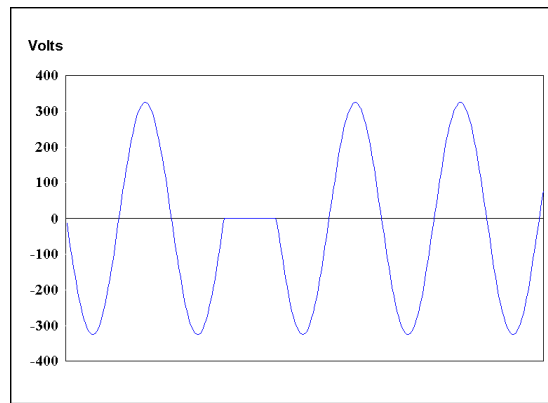


Figure 8 : Half cycle line drop-out simulation

## Conclusions

Electrical motor driven pumps, fans, blowers etc. need to be tested for supply line conditions they will encounter. These tests include not only different line frequencies, but also have to simulate voltage fluctuations, harmonics, and brown-out conditions. Programmable power sources facilitate these tests with relative ease.

Electronic motor controls are used in increasing numbers, either because they offer significant energy savings, or because variable speed operation is required or offers competitive advantages. Actual energy savings can only be determined through accurate power measurement under different operating conditions. Power sources, possibly with harmonics generation and analysis options, permit simulation and analysis of almost every electronic drive and line voltage condition.

\* *IEEE-Std-112-1991 may be ordered from: IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.*

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