APPLICATION NOTE #105

Understanding AC Source Specifications and Terminology

1. Introduction

Manufacturers of electrical and electronic equipment realize the need for product quality in order to maintain global competitiveness. Ensuring product quality invariably implies testing products for use with different and adverse power conditions that may exist. Unusual voltage and frequency combinations are common in many parts of the world and clean reliable AC power is not always available. To ensure safe and reliable operation of AC powered equipment and instrumentation, world power testing is now a requirement.

AC power sources are available in many forms, offering a wide range of capabilities and features. This makes the selection criteria for determining the proper AC power source for a given application all the more difficult. This application note reviews the various specifications that are commonly found on AC power source data sheets, their relevance, and their implication for the AC source's ability to meet certain testing requirements.

2. Load Considerations

The nature of the load that will be connected to the AC power source is very important in determining the correct type of supply. Generally loads can be classified as linear or non-linear. Linear loads consist exclusively of reactive, inductive or resistive components and can thus be characterized as an LCR network. Since all the elements of the load impedance are linear, the current drain on the AC power source is uniform and the resulting current waveform will follow the voltage waveform with a certain amount of phase shift. The amount and direction (lagging or leading) of the phase shift between the current and voltage waveforms is dependent on the resistive and reactive elements of the load. Common examples of linear loads are incandescent light bulbs and electric motors. Linear loads are often confused with resistive loads, whereas they are only a subset of all linear loads.

2.1 Linear Load Requirements

Linear loads are conceptually simple. However, they do have an impact on the AC power source requirements, especially with respect to in-rush current. For a purely resistive load, the in-rush current is the same as the steady state current. However, for reactive loads, it can be considerably higher, and depends on the phase angle of the voltage when power is applied to the load. If the load cannot be modeled to determine the in-rush current, then it should be measured with a current transformer and storage oscilloscope or suitable power analyzer. The worst case condition should be found. (for capacitive loads this is application of voltage at the 90 or 270 degree point). It is also necessary to determine the length of time that the in-rush current exceeds the rms or steady state value. For capacitors and transformers this is usually less than one cycle. However, for motors it can be several cycles, until the motor is up to speed (refer to figure 1).

The AC source is often required to supply a much higher current during the start-up period. If this start-up period lasts for several cycles, it is necessary to select an AC source with rms capability equal to the in-rush current required.

Many precision AC power sources avoid this need by including a programmable current limit time-out that can be set to accommodate loads that require longer startup periods. Effectively the source operates in a constant current mode at reduced output voltage during this time.

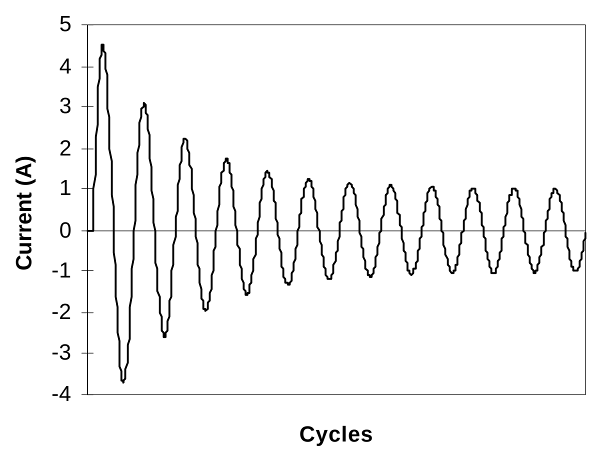

Figure 1 Inrush current

Practical examples of these types of loads are washers, dryers, refrigerators etc. and many industrial motor applications.

2.2 Non-Linear Load Requirements

A non-linear load is characterized by the fact that the current draw from the power source does not exhibit the same sinusoidal shape as the AC voltage. Rather, current is drawn in short momentary bursts or portions of a full period. This is most often caused by sub-cycle switching circuitry. Most modern office equipment uses switching power supplies to generate the internally required DC voltages. The proliferation of these types of non-linear loads is causing load current harmonic problems, which in turn may affect other equipment connected to the same circuit. In three phase networks it also results in high neutral currents which can cause transformers to overheat and circuit breakers to trip for no apparent reason.

While the rms current specification is important when considering an AC power source for non-linear loads, another specification becomes just as important. Since the current waveform is non-sinusoidal, the rms value of the current is no longer an indication of its peak value. (Refer to Figure 2) It is therefore necessary to characterize the peak repetitive current as well as the rms current. The ratio between a current waveform's peak value and its rms value is called crest factor (CF). A pure sinewave current waveform has a crest factor of √2. Current waveforms for non-linear loads usually have crest factors in excess of √2.

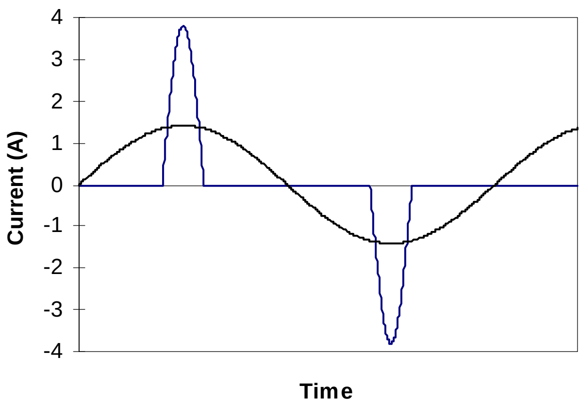

Figure 2 Non sinusoidal current waveform with a 2.7 crest factor and equivalent pure sinewave with equal rms value.

Pay attention to the way the AC power source's crest factor is specified. Is it specified under maximum load conditions? When the peak rms current is less than the maximum, the crest factor is usually much higher than under full load. Also, is the Crest Factor specified for the high voltage range only. It is normally higher at the high voltage range since the rms current is less when the voltage is higher, given the same total power output.

Finally, what level of voltage waveform distortion occurs under these peak current draw conditions. High crest factor could imply high distortion, which may be undesirable.

Usually, it is better to consider the absolute peak repetitive current specification than the CF specification. High CF AC sources usually command a premium above that of a lower CF source with a higher rms rating.

3. Other Parameter Considerations

The amount of total output power required by the load will normally determine the primary specification used. However, several other factors as discussed in the following paragraphs should be considered.

3.1 Output Voltage Ranges

Most AC power sources offer two output voltage ranges. The maximum power is available at the maximum output voltage. Therefore, if 10% over voltage is required at 115V, the source must have a capability of at least 126.5V. If 10% overvoltage is required at 240V, then the source must be capable of 264V.

Remember however that the VA rating of the source applies at the max. output voltage. A 3 kVA source, with a 300V max. output voltage will only be able to deliver 10 A rms. The max. power at 230V is therefore only 2.3 kVA. Also, unless the source has a lower voltage range, the max. power at 115V is 1.15kVA.

A 3 kVA source with 270V max. output has more power available where it will be used; i.e., 11.1 A rms at 230V, for a total power of 2.56 kVA, or 10% more. Do not specify or buy a source with a max. output voltage higher than is needed.

3.1.1 Steady State (rms) and Peak Current

Steady state current is probably the easiest to determine. However, don't forget to check the steady state current required at all test conditions. For example, certain regulatory standards require testing at 70% of the nominal input voltage. If the input circuit behaves in a constant power mode, then the current required will be 43% greater. The VA rating will have to be 43% greater than the steady state VA rating since the controlling specification is current.

3.2 Single or Three Phase

Equipment to be tested with the AC power source is usually either single or three phase input. However, some equipment may have options for single or three phase input, and some products that consume a great deal of power can operate at reduced power from single phase input.

If the AC power source is dedicated to a particular task, then the task will dictate the output configuration. However, many times an AC power source is procured as a generic piece of lab equipment. Many sources with an output power of greater than 3 kVA have a MODE option to select either three phase or single phase output. A useful feature if there are three phase applications, but not cost effective if applications are single phase (the most common) because a separate output stage is required for each phase.

3.3 Output Waveforms

A clean sine wave is a must. But how clean? The average utility has typical distortion of approx. 0.75%. It is only in rare applications, such as the testing of precision power measuring equipment that a signal with distortion of less than 0.5% is required.

Probably the next most important feature to have is the ability to start the waveform at a particular phase angle. This means that parameters such as in-rush current can be measured at the worst case condition, rather than taking many measurements and finding the highest one.

While all AC power sources should have the ability to generate sinewaves, many applications require more complex waveforms as well. This is particularly true for applications requiring line disturbance simulation, transient testing or MIL-STD-704 (Avionics). Using modern digital waveform generation techniques all of these capabilities can be competitively offered in an AC power source. Another capability that could be required is the ability to add defined harmonics to the power waveform (Refer to figure 3). Generally this requires a more sophisticated waveform generator, and is not needed for most applications. Any non standard waveform usually requires a higher bandwidth on the AC power source output stage. While the load may only operate at 60 Hz, the 51st harmonic requires a 3060 Hz bandwidth output stage.

Finally, although we have skipped frequency, it is probably the most obvious waveform characteristic worthy of some note. Most AC power source applications are at utility line power frequencies of 50 or 60 Hz, or 400 Hz for generic avionics applications. There

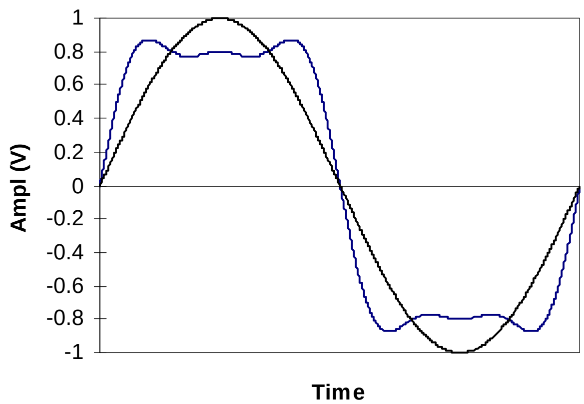

Figure 3 Both undistorted and Harmonically Distorted Sinewaves shown for comparison purposes

are other common applications at 17 Hz (European railway signaling), 45 Hz to 66 Hz (limit conditions for line power, often a necessary test to simulate auxiliary power applications), and 1 to 5 kHz (avionics preconditioned power generation)

3.4 Noise and DC Offset

Any unwanted noise on the output waveform can be considered as distortion, and is usually measured with a distortion analyzer. The noise may or may not cause problems for the user. True distortion is usually harmonically related to the fundamental output frequency, and is typically observed up to a few kHz, or the 50th harmonic. (Refer to figure 4)

Noise on the other hand may be low “beating” noise, which will often cause problems, or high frequency noise (especially from switching AC sources) which is usually out of the response range of the input circuitry of the equipment to be tested.

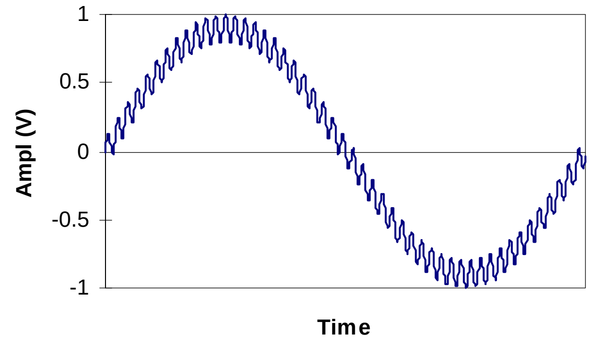

Figure 4 Example of Harmonic Noise

DC offset is another output characteristic that can be of importance. AC power sources that use an output transformer never exhibit any spurious DC on the output since any DC component is blocked by the transformer. AC sources capable of supplying DC on the other hand employ a direct coupled output stage and usually exhibit some spurious DC level even when in AC mode. This can be potentially dangerous for some types of loads. Always check to determine the type of AC source used and the load requirements to make sure they are compatible with respect to DC levels.

3.5 Voltage Regulation

An AC source will always have two types of voltage regulation specifications:

a) Line Regulation

Perhaps the easiest to understand. Usually specified as a voltage change on the output for a change on the input. This specification is not usually a differentiating factor between AC power sources.

b) Load Regulation

Load regulation is not as straightforward. For some applications the load regulation specification must be quantified between static and dynamic.

i) Static Load Regulation

Many precision AC power sources have the ability to connect sense lines directly to the load. The sense lines monitor the actual output voltage at the load, and adjust the output level of the waveform generator to compensate for any voltage drop in the load cables. If the load is interrupted, a certain amount of overshoot in voltage will occur, due to the time constant of the control loop and level detector.

Under steady state conditions, the load regulation will be superb. However, an accurate true rms detection system, and control loop with little or no overshoot will be far too slow to track the simulation of voltage transients.

ii) Dynamic Load Regulation

Dynamic load regulation is the instantaneous change in output voltage caused by a change in load current. This is due entirely to the output impedance and cannot be masked by sense connections. Consider an AC source with an output impedance of 500 mΩ, and a load current of 10 Amps. Connecting the load will cause an immediate voltage drop due to the output impedance of 5V. The same effect will be apparent from sudden changes in load current caused by test voltage transients. It is important to know the dynamic response of the AC source as well as the static response. Dynamic regulation performance will typically be expressed as a settling time. This can be tremendously important for transient and regulatory test applications. California Instruments has special controller options (-PT) for extremely fast response times.

3.6 Protection

Modern AC power sources are typically protected against overtemperature, overvoltage and overcurrent conditions. The method of protection used may affect the AC source's usefulness for a particular application. Two types of load protection methods are commonly used:

a) Constant Current mode (CC)

In Constant Current mode, the load voltage will start to decrease as soon as the current limit set by the user is reached. The reduction in voltage will cause the current to remain constant at this level. In case of a full short, the voltage will decrease to near zero. Effectively, the AC source turns into a current source under these conditions. This mode of protection may be required to start up electric motors or loads such as DC power supplies which have high momentary inrush currents at power-on. The non-conformance of the AC output voltage is less important than being able to start up these loads without tripping the AC source off.

b) Constant Voltage mode (CV)

When operating in a Constant Voltage mode, the output voltage level is maintained until the current exceeds the preset current limit. When the current limit is exceeded, the source will trip the output relay and return to a known default state. This type of protection is preferable when it is critical to protect the load for overcurrent conditions or if in-rush conditions need to be measured. Sensitive equipment would fall into this category.

4. Controllers

AC power sources generally are available with either a manual or a programmable controller. Aside from cost, the main consideration should be the intended application and the need for automation. Also keep in mind that many capabilities such as line disturbance simulation (LDS), transients etc. can only be offered by a programmable controller.

4.1 Manual controllers

Manually controllable AC power sources continue to be popular as they are easy to set up and use. Direct control knobs are typically available to adjust voltage and frequency. For laboratory use and infrequent test applications, where different AC characteristics are needed from time to time, a manual AC power source remains the most cost effective solution. One of the most convenient AC power sources from this point of view is the California Instruments WP Series. Models 1001WP and 1251WP offer push button control of frequency (50 or 60 Hz), voltage (110, 115, 220, 230 and 240), and limit testing.

4.2 Programmable controllers

Bus control is usually accomplished through IEEE-488 (GPIB) although some controllers offer RS232C control as well. The number of internal program registers available in an AC power source can be an important consideration when test throughput is critical.

Downloading test steps to internal register for quick recall under program control can significantly speed up the test process. Some AC power sources, such as the California Instruments' L Series, allow linking of registers enabling the unit to sequence through multiple program steps without the need for controller intervention.

4.3 Measurements

Built in measurement capability in an AC power source is usually a function of the controller type used and is beyond the scope of this application note. For a review of AC Source measurements, refer to California Instruments Application Note # 106, "Understanding AC Power Source Measurements".

5. Summary

Selecting the proper AC power source for present and future applications is a critical task that should be undertaken carefully. Define the load the source will drive and, armed with this information, an applications engineer from California Instruments can assist you in selecting the proper AC power source.

Contact California Instruments:

FAX: 677-0940
Email: sales@calinst.com
Web page: http://www.calinst.com

California Instruments

9689 Towne Centre Drive, San Diego CA, 92121 **() 677-9040** **FAX : () 677-0940**