



## Understanding Electric Power Characteristics

### **Introduction**

Electrical power is usually taken for granted. Once a piece of equipment is plugged in the electrical power, it is seldom thought of again. It is important for any user of electrical appliances to remember that every thing that is manufactured and the electrical distribution system within a customer's premise requires maintenance. Electrical power has many unique characteristics and at times there is a mismatch between an equipment's power requirements and the available power. The purpose of this power note is to better educate the reader regarding these electrical characteristics.

### **Voltage Range**

The *American National Standard ANSI C84.1*<sup>(1)</sup> establishes nominal voltage ratings and tolerances for 60-hertz (alternating current, AC) electric power systems above 100 volts and through 230, 000 volts. Voltage operating ranges are recommended for two voltage categories: 1) the service voltage, typically the point of connection between utility and customer; and 2) the utilization voltage, typically the termination point to equipment. The utilization voltage range takes into account a voltage drop within the end user's distribution circuits. ANSI C84.1 expects equipment to operate at service voltages between 95% to 105% with a utilization voltage range of 87% to 106% (120V to 600V) Refer to ANSI C84.1 for additional operating voltage ranges). Voltage levels outside this range may occur because of conditions beyond the control of the supplier, user or both<sup>(1,2)</sup>. Equipment may not operate satisfactorily under these conditions and protection devices may be utilized to protect against equipment damage. Both ANSI C84.1 and our rules warn the customer that deviations will occur but we have no current means to forecast their occurrence nor do we maintain a complete history of their occurrence. This lack of forecasting or history makes it extremely difficult to make economic decisions regarding mitigation measures.

### **Electric Power**

Electrical power in an AC circuit has three components. The component we are most familiar with is called real power measured in watts (typically kilowatts). Real power is considered to be the work-producing component. Another component is reactive power measured in volt-amperes-reactive (VAR). Reactive power is not used to do work but is needed within an electrical system to operate equipment such as motors and transformers. Apparent power comprises both real and reactive power and is measured in units of volt-amperes. Textbooks and common use refer to watts as real power which is, in fact, misleading for two reasons. First, all electrical equipment is rated in apparent power, voltamps because it must handle the full RMS current. Secondly, distribution losses are a function of total apparent power not just watts; this can be appreciable and costly for someone. It is an error to assume that reactive or harmonic currents should not be of concern.

### **Power Factor**

In an AC circuit, real power, kW is less than or equal to apparent power, kVA. The ratio of real power consumed to apparent power is the power factor. True power factor includes all frequencies, not just 60Hz. Facilities with a low power factor require a larger amount of reactive power, kVAR, as a percentage of the true power, kW. Power factor adjustment is calculated for larger customers, over 400kW, to appropriately charge for the larger percentage of reactive power used. At PG&E we average the power factor over the entire monthly billing period. Modern non-linear loads are beginning to create a major concern with true power factor versus

displacement power factor. Displacement power factor is what utilities traditionally measure because of limited capabilities of the revenue meters. Customer loads such as Adjustable Speed Drives and most any rectifier can have a high displacement power factor but low true power factor. These non-traditional loads create harmonic frequencies other than 60Hz. These other harmonic currents create higher total true RMS currents and therefore higher kVA. These are not measured by current utility revenue meters. The problem is that the utility does not measure kVA and therefore can underestimate total RMS current.

### **Single Phase Protection**

Three-phase systems will at times operate with one of the phases open, this condition is called single-phasing. The causes of single phasing are too numerous to mention and the open phase may be within your facility or somewhere on the utility system. Single phasing is dangerous to three phase loads, especially three phase motors. Since 1971 The *National Electric Code*, *NEC*<sup>(4)</sup> has required a protective device in each of the three phases to minimize motor failures caused by single-phasing. When overcurrent protection is properly sized, 25% over full load, motor burnout due to single phasing should be rare.

For very sensitive or expensive equipment, a digital electronic breaker can be used with very close tolerances for voltage and current imbalances, over and under voltage, and for current overload and very fast fault currents.

### **Electrical Disturbances**

Electrical disturbances come in many forms and are a reality of electrical distribution systems. *Recommended Practice for Monitoring Electrical Power, IEEE Std 1159*<sup>(3)</sup> has categorized most disturbances into one of the following: 1) short duration variations (interruptions, sags or swells); 2) long duration variations (interruptions, sags or swells); 3) transients, 4) voltage imbalance and 5) wave form distortion (i.e. harmonics). It can not be over emphasized that these electrical phenomena will occur on all typical systems at some point and time. The impact of the phenomena depends on the sensitivity of the equipment. Every facility should consider the impact of electrical disturbances on the various equipment and implement the appropriate mitigation. *IEEE Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment, IEEE P1346*<sup>(6)</sup> is to recommend a standard methodology for technical and financial analysis of compatibility of process equipment with the electrical power system. (Note: IEEE P1346 is intended to be applied at the planning or design stage of a system where power supply and equipment choices are still flexible and incompatibilities can be resolved. The cost to retrofit and fix problems after operation has begun can easily be hundreds of thousands of dollars more than to address the problem in the planning stages.)

### **Phase Balance**

Three-phase systems are designed to operate at maximum efficiency when the load on each phase is balanced. Three phase systems being 100% balanced is only theoretically possible. In order to operate the electrical system and equipment efficiently ANSI C84.1<sup>(1)</sup> recommends that "Electrical supply systems should be designed and operated to limit the maximum voltage unbalance to 3 percent when measured at the electric-utility revenue meter under no-load conditions. PG&E will attempt to maintain the voltage balance at no more than 2.5 percent imbalance<sup>(2)</sup>. Actually, the system usually runs between 1 and 1-1/2% imbalance. In order for PG&E to maintain this balance, each customer must strive to keep the difference in amperes between any two phases at peak load =< 10 percent or 50 amperes (at service voltage) whichever is greater.<sup>(2)</sup> The rated load capability of polyphase equipment is normally reduced by voltage unbalance. It is very important to note that some equipment manufacturers require a tighter voltage balance than the ANSI C84.1 requirements of 3 percent. This requirement is not realistic and extreme caution should be taken when purchasing this equipment. For example, *National Electrical Manufacturers Association (NEMA) MG 1*<sup>(5)</sup> requires a polyphase motor

derating factor of 0.9 with a voltage unbalance of 3 percent. This disparity can create a conflict between a manufacturer's warranty coverage and a customer's expectations. In practice, most motors run at around 60% loaded, so 3% imbalance does not typically create a problem. A more typical problem occurs when a customer's equipment has a current imbalance trip set at 5%. This is totally unrealistic, since the current imbalance drawn by a motor runs between 6 and 10 times the voltage imbalance.

### **Special Equipment Requirements**

Electrical motors require a significant amount of current during start-up (it is not unusual for the start-up current to be six times normal running current). During this startup condition, the voltage may sag to levels that create problems for other equipment operating, or a visual flicker. If this voltage sag is significant, corrective action may be required to limit the startup current to minimize impact on the operation of other equipment. Other equipment such as welders and X-ray machines may require special installation to minimize the impact on the electrical system in order to not impact the operation of other equipment connected to the system. Customers are required to advise PG&E of any major loads that might create a voltage sag or flicker during operation. Generally loads over 50kW/HP are of concern. The customer is required to take corrective action.

### **In summary**

This Power Note has discussed some aspects of electric power that we do not normally concern ourselves with, but can have major impact on sensitive and expensive equipment.

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### **References:**

- (1) *American National Standard for Electrical Power Systems and Equipment - Voltage Ratings (60 Hertz), ANSI C84.1 -1995* [\(1.2\)](#) [\(1\)](#)
- (2) PG&E Rule 2 - Description of Service as approved by the California Public Utility Commission [\(2\)](#)
- (3) IEEE Recommended Practice for Monitoring Electrical Power, IEEE Std 1159-1995 [\(3\)](#)
- (4) National Electric Code, NEC-1996 [\(4\)](#)
- (5) National Electrical Manufacturers Association (NEMA) Motors and Generators MG 1-1987 [\(5\)](#)
- (6) IEEE Recommended Practice for Evaluating Electrical Power System Compatibility with Electronic Process Equipment, IEEE Std P1346 (pending final approval) [\(6\)](#)

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