

## Your Reliable Guide for Power Solutions

To fulfill our commitment to be the leading supplier in the power generation industry, the Buckeye Power Sales team ensures they are always up-to-date with the current power industry standards as well as industry trends. As a service our **Information Sheets** are circulated on a regular basis to existing and potential power customers to maintain their awareness of changes and developments in standards, codes and technology within the power industry.

### The Paralleling of Generator Systems- Basics, Applicable UL Codes and When to Use

Paralleling in electrical generator terms is the combination or synchronization of two electrical inputs by matching the output-voltage waveform of one electrical system with the voltage waveform of another system. Synchronization can be between two or more generator systems or between generator systems and a utility supply. The Designer of a electrical system particularly above 500kW, must consider the merits of a parallel generator system over that of a single generator system.

**This information sheet discusses paralleling systems, the basics of operation, issues to be considered, the merits of a parallel system over that of a single generator and the applicable UL standards specified for parallel systems with the utility.**

**A system designer considers three principal issues when weighing the merits of a parallel system**

**Redundancy:** Paralleling an incoming set with an out going set before the out going is switched out and shut down ensures a soft transfer of power and avoids loading the batteries of an UPS system.

**Capacity:** Paralleling for capacity allows additional sets to be powered up as load demand increases or switched out of a system as the load decreases.

**UL codes:** System designers can choose a variety of systems but must comply with UL891 and UL 1558 if paralleling with a utility. Non-UL compliant controls may be used only on systems not connected to the utility.

#### **Key principles of operation when paralleling**

For two systems to be paralleled, each must have the following matching characteristics for correct synchronization:

**Phase Number:** Both systems must be either single phase or three phase for correct synchronization.

**Phase Rotation:** All three phases of each three phase system must be matched to avoid power surges and excessive electrical or mechanical stress. Matching just one phase is not enough. (See diagram one and two)

Phases A, B and C are 120° apart and may rotate in either A-B-C or A-C-B sequences. Use a rotation meter to see if the sequences match.

**Frequency:** The standard frequency is 60Hz in the US and 50Hz in some countries. The frequencies of the two systems must be the same for correct synchronization. 60 cycles per second cannot be synchronized with 50 cycles per second.

**Voltage:** Each system being matched must be configured for the same voltage.

**Voltage Phase Angle:** Phase angle matching requires that the wave forms rise and fall in together with no angle difference. The potential difference between the phases being matched must be zero. With a synchronous generator, matching is achieved by speed control. (See Diagram Three)

#### **The advantages of choosing a parallel standby generator system over a single larger generator**

The system designer must consider several factors when comparing the merits of one large standby unit and the two or more smaller, parallel units. As generator set manufacturers apply the latest electronic control and measurement technology to their products and improve cost, space and complexity, they provide designers with more reasons to select paralleling.

#### **Reducing light loading of the prime mover:**

Loads do not remain at a constant level in most installations. Variations in power demand can cause a single larger generator to run at loads below 30% of capacity, which could cause wet stacking. (See information #9 on Wet Stacking) Prime movers are designed to run most efficiently at approximately 75% of full load.

#### **Providing redundancy and greater reliability in systems with critical and noncritical loads:**

When systems must handle both critical loads required to prevent human or economic loss and less critical loads where constant power isn't as critical, system designers can use parallel systems to increase reliability. If one standby unit fails to come on line, backup power from one or more parallel units supplies the critical load.

If the reliability of a single generator standby set (N) is 98%, an N+1 system is 99.96% reliability and N+2 99.999% reliable.

#### **Prime mover options are limited above 2000kW:**

Most manufacturers above 2000kW do not offer 1800rpm 60Hz generator sets. If higher loads are required, paralleling smaller 1800rpm generator sets achieves much more than 2000kW with the added advantage of redundancy. It also avoids having to drop down to the lower 1200rpm 60Hz speed of larger generator sets.

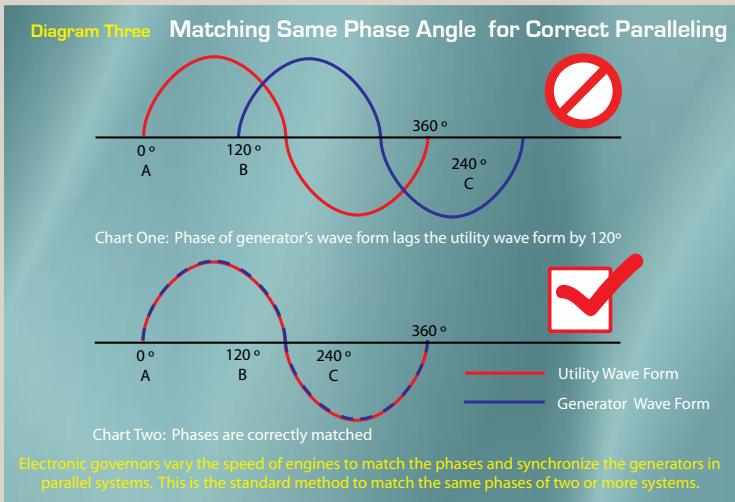
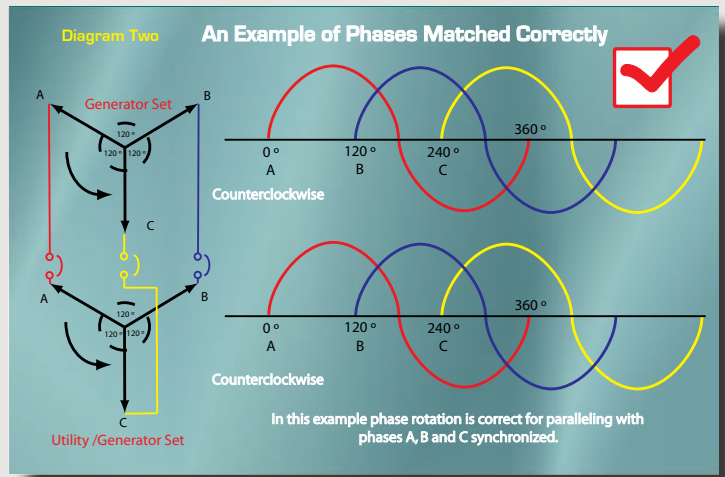
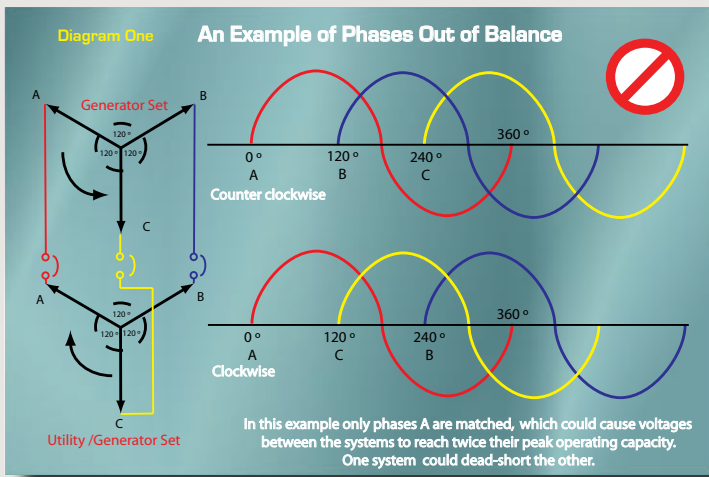
#### **Cost of generation in terms of \$ per kW:**

Some manufacturers claim the \$ per kW of generator sets exceeding 600kW are higher than those in the 400kW to 600kW range because more engines are manufactured in the lower kW band, resulting in lower unit costs.

#### **Paralleling switchgear controls: (See photo)**

Advances in electronics have made it much easier for the operator of a power plant with several generator set installations to switch between the various sets and the utility supply. Many manufacturers offer modular systems that allow the additional systems to be paralleled as load increases. Controls not complying with UL 891 and UL 1558 offer some cost savings, but cannot be used to parallel with the utility power. Also in some cases, costs are reduced by not putting a copper bus in the panel. This could mean using the installations distribution panel as the bus which is not a recommended practice.

# Each phase within the power sources being paralleled must be matched



**Phase Angle Match**

Each phase of individual voltage wave form must be synchronized when two or more systems are being paralleled.

If there is an attempt to parallel when generator voltage is lagging utility voltage by 120° the generator shaft could try and turn 120° relative to the engine shaft causing damage.

An electronic governor controlled by the paralleling switchgear varies engine speeds within the system to produce matched phases.

## Typical Parallel Applications

- 1) Standby**  
The generators automatically synchronize and connect to a parallel bus via a ATS system.
- 2) Utility breaker sensing**  
No ATS, the system senses utility failure starts required generators, synchronizes them to paralleling bus and tie breaker closes to connect to load.
- 3) Prime Power**  
System starts all generator sets, the units synchronize and connect to paralleling bus.
- 4) Isolate (Interruptible Rate)**  
Starts, synchronizes and connects generators with the utility when a predetermined load level is reached and a utility breaker opens.
- 5) Base Load (Peak Shave)**  
Generator sets start and synchronize to bus, which then parallels generator bus with utility and generator bus tie breaker closes. Generator power remains constant when less the load utility makes up the difference when more generator feeds into the utility.

## Paralleling switchgear complying with UL Codes 891 and 1558



Touch sensitive screen provides control and monitoring of all systems. Space is considerably reduced from older analog systems.

Modular construction permits easy expansion of the system.

Digital controls over traditional analog metering systems offer a smaller footprint, ease of use, and command and control of multiple power sources.

UL Codes 891 and 1558 have been established to ensure the safety of paralleling when synchronizing with the utility. A designer of a system should consider the same safety standards when paralleling systems independent of the utility.



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