ULTIMATE SERVICE ASSOCIATES
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The ultimate solution for maintaining your nationwide generator network

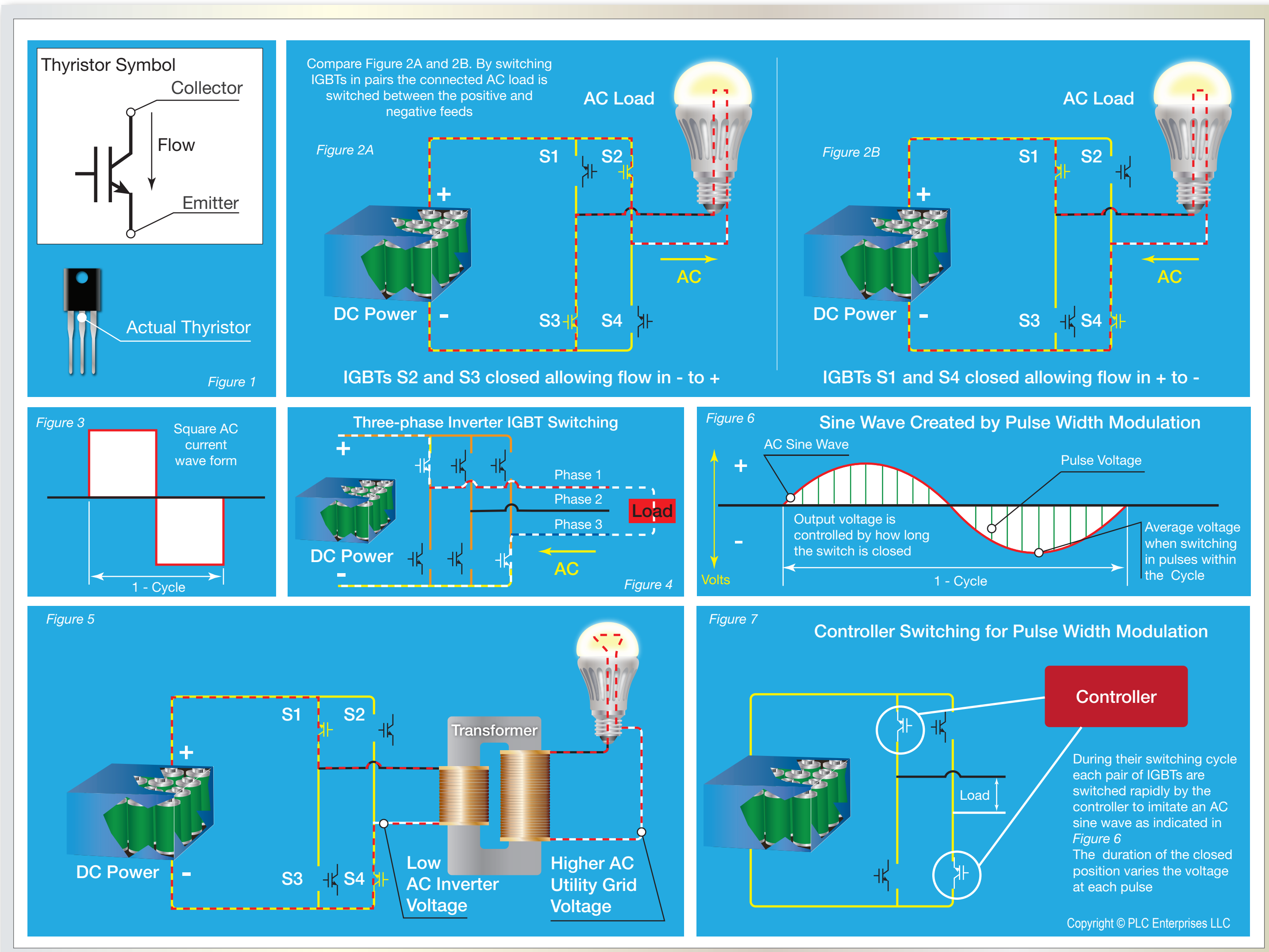
Inverters Within Generator Power Systems

1.0 Introduction:

A generator system provides power to many applications that have an inverter component. An inverter is a device that converts Direct Current (DC) to Alternating Current (AC). Generator applications that have an Uninterrupted Power Supply (UPS) component frequently have an inverter component within the system. As more generators are used in conjunction with renewable energy, there are more applications with an inverter component because renewable energy, such as solar arrays, initially produce DC power that must be converted to AC power. Why applying generators to applications with an inverter component system designers must consider the characteristics of an inverter load.

This information sheet discusses applications that use inverters, the characteristics of an inverter load that can influence generator selection, how an inverter works, and how it is controlled.

Operation of an Inverter



To fulfill our commitment to be the leading network service provider in the Power Generation Industry, the USA, Inc. team maintains up-to-date technology and information standards on Power Industry changes, regulations and trends. As a service, our **Information Sheets** are circulated on a regular basis, to existing and potential Power Customers to maintain awareness of changes and developments in engineering standards, electrical codes, and technology impacting the Power Generation Industry.

1.0 What is an Inverter:

An inverter is an electronic device that converts DC to AC current. It is a solid-state device using electronic components. An inverter is the opposite of a rectifier, that converts AC to DC current, but frequently they are found in the same application.

2.0 Generator Applications that have an Inverter Component:

The most common electrical power supply applications with an inverter component are those that include a UPS and renewable energy components. The following details how the inverter is applied to the application.

2.1 UPS:

A UPS ensures no power is lost to the connected load when switching from one power source to another. For example, when the utility goes off-line, in the short time the standby generator is running up to speed, energy stored in a battery, that has DC output, flows to the load through and inverter converting the battery current from DC to AC: *(See UPS info Sheet)*

2.2 Renewable Energy:

The two most common renewable energy sources, after hydro generation, wind and solar, have an inverter component.

- **Solar Array -** Solar panels produce DC current; this is converted to AC through an inverter.
- **Wind Turbine -** Generally a wind turbine generates AC current. However, frequently wind generated energy is synced with the utility grid and the AC energy generated is rectified to DC for it to flow through an inverter that ensures the frequency and phase of the AC power is in line with that of the grid.

2.3 Battery Banks:

As battery technology evolves batteries are being applied as standby power systems. DC energy stored in the battery flows through an inverter to supply AC power to the load. *(See Battery Standby Info Sheet)*

3.0 Explanation of How an Inverter Operates:

As stated, an inverter is an electronic piece of equipment with no moving parts. The principal electronic components of an inverter are "Insulated Gate Bipolar Transistors" generally referred to a IGBTs.

3.1 IGBT Function

An IGBT is a type of transistor, called a thyristor, having the capability to switch large amounts of power very rapidly. An IGBT is a unidirectional device; this means it can only switch current in a forward direction from the Collector to the Emitter. *See Figure 1 for Thyristor Diagram and Symbol.* When IGBTs are opened and closed in pairs across a connected load, an AC current can be imitated from a DC source. *See Figure 2a and 2b*.

When switch S2 and S3 close simultaneously, current flows to the connected load in one direction as indicated in Figure 2a. Then when switches S1 and S4 close together, the current flows to the load in the opposite direction as shown in Figure 2b. Thus, the connected load sees an AC current.

3.2 Resultant AC Waveform

The switching process simulates an AC current, in a cycle one half is a positive current, the other a negative current. An oscilloscope connected to the load terminals shows a square-shaped graph; *Figure 3.* While some AC loads would operate with this type of AC input, most, particularly electromagnetic loads like electric motors, would not, and would require a sine wave.

3.3 IGBT Controller

The opening and closing of the IGBTs is actuated by a controller. When the controller switches the IGBTs 120 times per second, the current connected to the load alternates in one second 60 times, which is 60 cycles or 60hz. For 50 Hz the IBGTs would switch 100 times a second.

3.4 Three Phase

The description given above in clause 4.1 is for two pairs of IGBT switches. In a 3-phase inverter there will be three pairs of IGBTs opening and closing in sequence to simulate a 3-phase AC current. *See Figure 4*

3.5 Matching Inverter Output to Grid Voltage with Transformer

Most DC power sources, batteries, solar arrays, and fuel cells, have a lower DC voltage than the grid system. In North American the connected load is from 110 to 480 volts. A transformer converts the lower AC voltage output of the inverter to the AC output to the load that matches the grid voltage. *See Figure 5*

4.0 Controller and Pulse Width Modulation:

As stated, if we just switch the IGBTs in pairs, the alternating current to the load, as seen on an oscilloscope, will be alternating positive and negative squares, but the AC utility power is a smooth sine wave *See Figure 6*

A controller, in the inverter, rapidly switches the paired IGBT switches feeding the connected load multiple times within a cycle, enabling the load to see a smooth AC sine wave. The rapid switching is in pulses. Each pulse will vary in width (time open) and time between pulses; this process is called Pulse Width Modulation. With a cycle (one second) multiple pulses allow a set amount of current to flow per pulse. The timing between pulses, and duration of the pulse imitate a sine wave to the connected load. The more switching, the smoother the AC sine wave to the connected load *See Figure 6*

The following is undertaken by the controller when switching per *Figure 7.*

4.1 Voltage Level

The controller sets the output voltage by controlling how long the IGBT switches are left open. The longer the switch remains open, the higher the voltage; therefore the inverter can be adjusted to give a wide range of voltages.

4.2 Frequency

The controller adjusts the frequency the load sees by controlling how often the pair of IGBTs are switched in one cycle. As stated, if the controller switches the IGBTs 120 times per second, the frequency is 60Hz, and 50Hz when switched 100 times.

4.3 Smooth AC Sine Wave

Per *Figure 7,* the controller opens and closes the individual pair of IGBTs in pulses; it produces a smooth sine wave by controlling the length of the pulse and the duration between the pulses. This is the Pulse Width Modulation component.

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