7. UPS Topologies

What is UPS topology? What does it mean for you and why should you care?

Topology can be defined as the configuration of a UPS system unit. We are speaking specifically of a single module. This differs from the UPS system's configuration as it relates to multi-module configurations. The topology or configuration is the makeup of the UPS system, in other words, which building blocks make up the unit.

To maintain conformity, the Institute of Electrical and Electronics Engineers (IEEE) Standard 446-1995 , "Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications," was used as much as possible to identify and define the types of UPS topologies.

Manufacturers refer to different systems with terms other than those defined by IEEE, but these are marketing techniques, and at the end of the day all can be identified using one of the IEEE definitions.

IEEE Standard 446-1995 defines two categories of UPS topologies: double conversion and single conversion. It defines several other subcategories of the single-conversion UPS system:

- Line Interactive
- Tri-port
- Ferroresonant

Each topology will protect against power problems in distinct ways. The level of protection and criticality of your load will influence what type of topology you want.

Online vs. Offline

A quick note about online vs. offline UPS systems: the IEEE does not define online or offline UPS systems. These labels are used by the industry and manufacturers to promote or better understand the various products.

Double-conversion UPS topology would once have always been considered an online system. But with today's eco and standby modes, double-conversion systems can now be labeled offline, depending on their mode of operation.

Several line-interactive UPS topologies are online systems, but they are not double-conversion. Many engineers and facility personnel don't like the term line-interactive, so the terms online and offline were coined.

Double Conversion

One of the original UPS system designs was the double-conversion system, which uses all the major components discussed in Major Components. (See Figure 27.)

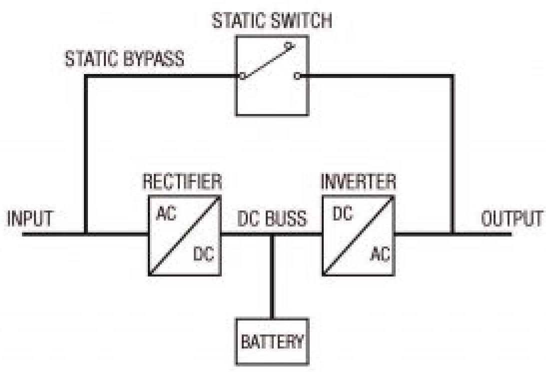

Figure 27

This topology uses a rectifier to change incoming AC voltage into DC voltage. This DC voltage is then used to charge the batteries and supply power to the inverter. The inverter in turn changes DC voltage to AC voltage, which is supplied to the load.

Conversion of AC to DC and back to AC requires two conversions, thus the name double-conversion.

A common question or concern is how long the break in power is between the incoming power failure and the UPS system operation from batteries. For a double-conversion UPS system, this break is nonexistent. In other topologies, there can be a momentary break of several milliseconds.

Eco Mode

With the current climate of increasing efficiency and decreasing overall total cost of ownership, several manufacturers have added a new mode of operation to the double-conversion UPS system. The mode is often called eco mode, just as in newer automobiles. Each manufacturer has a unique name, and each accomplishes it differently, but the result is the same—the rectifier and inverter are "phased back" and utility power is passed directly to the load, typically through the static switch. Phased back means the power components are on and ready to work at a moment's notice, but they are not doing any work. Like an electric car at a stoplight, the engine is not running, but as soon as you press on the gas it springs into action.

If the system senses a problem with the input power, it will instantly phase on the inverter to support the critical load. The batteries will be charged by either a separate charger or the rectifier will be phased on every so often.

Eco mode eliminates the losses of a loaded rectifier and inverter, allowing some of these UPS systems to achieve ninety-nine percent efficiency.

Single Conversion

There are several types of single conversion systems and these are sometimes referred to as "line-interactive." Line-interactive systems are a form of single conversion, but not all single conversion systems are line-interactive.

The major difference between a single conversion and double-conversion system is that single conversion does not require all of the incoming AC voltage to be converted to DC. During normal operation, these systems provide power to the critical load through a combination of components to produce an impedance. These components include transformers, inductors, and capacitors, depending on the topology and the manufacturer.

A single conversion system uses an inverter to convert the battery power to AC when a problem is sensed with the input power.

There is a battery charger that keeps the batteries charged during normal operation and recharges them after a power outage. Sometimes a single conversion system's charger is not large enough to support the inverter.

Line-interactive

A line-interactive UPS system is a form of single conversion.

The inverter "interacts" with the line power through the use of transformers and inductors to buck or boost the voltage to the critical load. This same inverter is then used during a complete input power outage to supply power to the critical load using the batteries to power the inverter. (See Figure 28.)

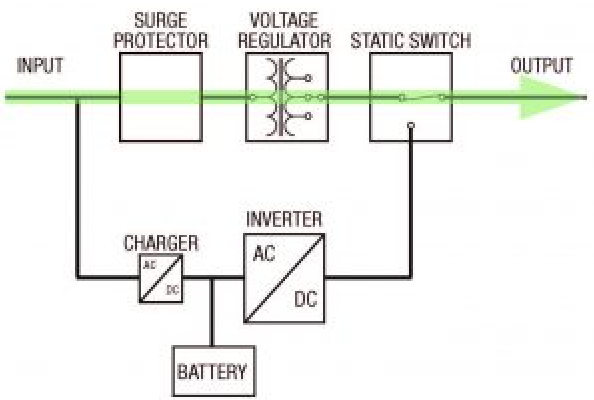

Figure 28

A significant limitation of a line-interactive UPS system is its inability to free run without using batteries. If the frequency of the input voltage is not within the UPS system's program window of operation, it uses its batteries to operate the inverter. When the batteries have become exhausted, it will shut down on DCUV, even if input power is available.

This normally happens when operating on a generator. The generator frequency will fluctuate from nominal by more than the UPS will handle. This can happen when a large load like a motor or air conditioning system is abruptly applied to the generator.

A UPS system could have its frequency window set for sixty HZ +- one percent, meaning the input to the UPS must be between 59.4 and 60.6 HZ. If the frequency is outside that window, the UPS must run on batteries to keep its output frequency within that window. In this instance, we will get a call from a customer that their UPS has shut down and dropped the load. But the generator is running, causing a great deal of confusion and frustration.

To correct this issue, the input voltage frequency window would need to be opened, often to three percent or even five percent when experiencing this problem. This allows the UPS to stay synced with the generator and not use the batteries.

The load will be exposed to the frequency variation. Today's loads are not as frequency-sensitive as older ones, but this needs to be verified before the change is made.

Other options are to increase the size of the generator or remove the loads causing the frequency deviation. These can be cost-prohibitive or feasibly impossible.

Tri-port

The name tri-port comes from the fact that the input, inverter, and load all share the same transformer core, forming three ports. (See Figure 29.) This allows for correction of any input voltage deviations, but because the inverter is in parallel with the main input voltage, it need not support the entire load. This increases efficiencies considerably.

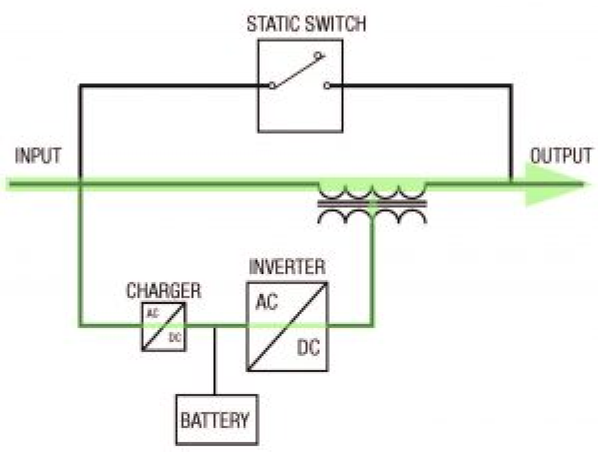

Figure 29

The inverter can be configured to act as a battery charger during normal operation or a separate charger can be used.

Because the inverter often runs constantly, this topology is considered online. However, it is not double conversion because it interacts with the input line voltage, making it a line-interactive UPS system.

The tri-port UPS system has the same limitation as a line-interactive UPS system—its inability to free run without using batteries.

Ferroresonant

A ferroresonant UPS unit is one that uses a special transformer called a ferroresonant. Most transformers operate in a specific voltage window allowing for the highest efficiency; a ferroresonant transformer is designed to operate fully saturated. This reduces efficiency but allows for a very stable voltage and frequency output.

Using a combination of a ferroresonant transformer and capacitors, a tank circuit is created that stores energy. (See Figure 30.) This energy is then used during an outage until the inverter can start and support the load from batteries. Tank circuits have several electrical cycles of power, just long enough for the inverter to start.

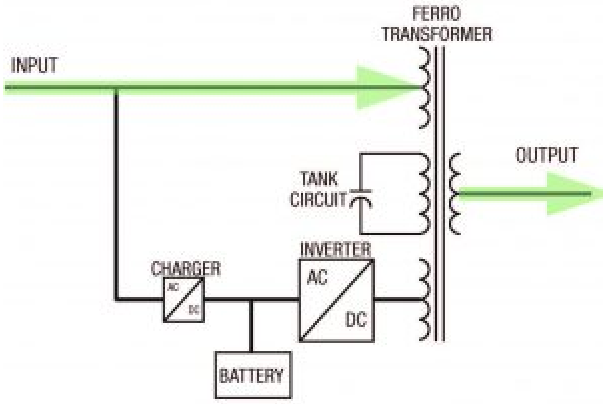

Figure 30

The ferroresonant transformer provides for line condition, noise isolation, and voltage regulation because it is operated in the saturation region. Efficiencies are low for a modern UPS system and are not generally used in data centers or network closets. Because of how robust they are, some are still used in certain industrial applications.

Choosing the Correct Topology

Which product to buy—the most expensive, the highest-rated, the cheapest? All of us struggle with these questions in our personal purchases and our businesses.

About the same time I started in the UPS business, a new product was released in the U.S. called the Silcon. It was marketed as Delta Conversion, which the IEEE defines as a tri-port system, and it enjoyed tremendous success in the market. Priced below much of the competition and sold by APC, it took the market by storm. APC was well known in the IT marketplace for its small, single-phase systems and had a loyal following of IT professionals. APC marketed this three-phase product to these loyal customers when the market was doing well and companies had the capital to purchase the needed UPS systems.

From the beginning, several problems indicated the Silcon UPS was not the Cadillac of the industry. A coworker of mine hated the system and criticized it at every opportunity; it was junk. I was young and respected this worker's opinion with very little questioning. He had more experience in the UPS industry.

There was one major problem with this theory—customers bought them. A lot of them. During my first few years, I spent half my working hours starting Silcon units and completing preventive maintenance and corrective services—much more than any other product.

Why did customers love them, and maybe more important, why did technicians and many engineers hate them?

They got the job done ninety percent of the time. They were inexpensive to buy and repair, easy to purchase and easy to install. From the IT manager's perspective, the "perfect" solution to their problem, cheap UPS backup.

I own a Honda CRV that works great for eighty percent of my purposes and gets great gas mileage. It fits into the ever-shrinking parking spots and parking garages and has plenty of room for our family trips to the beach. However, it is not well-suited for work on the family farm; for that we need a pick-up truck. As much as I would like a new one, the amount of times we need it doesn't justify it. My fifteen-year-old Ford F150 fits our budget and matches our needs better.

The Silcon UPS system fit many customers' budgets and matched their needs during its heyday in the early 21st century.

What my coworker failed to understand, is not every customer needed the most reliable, most robust UPS system on the market. Many needed a quick, easy, inexpensive solution to provide battery backup for major power abnormalities.

The point of this story is not to sell a Silcon UPS system. The manufacturer of the Silcon stopped selling it in 2005. My point is everyone's purpose for a UPS System is different, just as everyone's budget and need for a vehicle are different. What works for my company will not work well for someone else.

We see installations where the UPS system is not a great fit. The end user needs more reliability than the system can provide. This is why the purpose of the UPS System must be defined and the proper system installed to match.

There is no right or wrong system, just the one that best fits your application and budget. Knowing the advantages and disadvantages of each of the UPS topologies is important when deciding which one to purchase. An honest look at what the risks are and performing a cost-benefit analysis is critical. This will take more time and research upfront but will save money and heartache later.

Table 2

Types of Power Problems (Input to the UPS System)	How They are Corrected			
	Double Conversion	**Line Interactive**	**Tri-port**	**Ferroresonant**
Interruptions	The inverter of the double-conversion UPS system will continue to draw power from the DC Bus. It will not know that the input has been interrupted. But the DC Bus will begin to draw its power from the batteries. Often you will hear someone ask how long it takes the UPS to switch to batteries. In a double-conversion system, there is no switch or break.	There is an outage of approximately twenty milliseconds while the inverter starts. After the inverter starts the system works as all others, the batteries support the inverter until input power returns or the batteries are exhausted and the system shuts down. This short outage does not affect most modern loads.	The inverter is always running in a tri-port system. When the input power fails, the inverter will draw power from the batteries instead of the utility. The batteries will continue to support the inverter until the power returns, or the batteries are exhausted.	The tank circuit will support the load until the inverter starts. Energy from the batteries will be used by the inverter until power returns or the batteries are exhausted and the system shuts down.

Voltage Fluctuations	Because the rectifier of a double-conversion UPS system converts all incoming AC power to DC; this small change in voltage will be converted to DC and provided to the inverter. No change in the operation of the UPS system is required and the fluctuation will not be passed to the load.	A line-interactive UPS system will have an adjustable setting to handle input voltage ranges. If the voltage is within this tolerance, it will pass it directly to the load. If outside this tolerance, it will use the inverter to buck (lower) or boost (raise) the voltage to the appropriate level.	The inverter of a tri-port system is always running and making adjustments to the input power. Any voltage fluctuation on the utility will be corrected by this operation, providing regulated power to the load.	The ferroresonant transformer operates saturated, providing for inherent voltage regulation. The inherent properties of a ferroresonant transformer provide regulation for voltage fluctuations with no need to change its operating condition.
Transients	The rectifier of a double-conversion UPS system converts all incoming AC power to DC; this small change in voltage will be converted to DC and provided to the inverter. It will not be passed directly to the load.	The input of a line-interactive UPS system is equipped with a noise/surge protector; this is designed to block transients.	The input to a tri-port system consists of an impedance in series with the input power, often an inductor. This impedance will block transients from the load.	Because a ferroresonant transformer operates completely saturated, it will block transients to the load.

Waveform Distortion	Each UPS model will have a specification or tolerance that it can operate from. If the distortion is within this tolerance, the rectifier will convert the distorted waveform to a DC voltage, which removes the distortion due to its inherent physical properties. If the distortion is outside the UPS system's tolerance window, it can disconnect from the input source and operate on batteries until the source is back in tolerance.	The input noise/surge filter will remove any distortion it is able to. The remainder will be passed along to the load, or if the system senses the issue, it will operate from batteries until the problem is corrected or the batteries are exhausted.	Using the input impedance–the inverter–the system will correct for the distortion if possible. If it is unable to correct for it, the system will either pass the remainder of the distortion on to the load or operate from batteries.	The ferroresonant transformer will block or correct any distortion it is able to, and the rest will be passed along to the load. If the system detects the problem, it could operate from batteries until the issue is corrected or the batteries are exhausted.

Sag/Undervoltage & Swell/Overvoltage	The rectifier of a double conversion UPS System is a constant power device. This means when the voltage decreases, the current increases, providing a steady DC voltage to the inverter. The system does not need to do anything for this to happen.	A line-interactive UPS system will have an adjustable setting to handle input voltage ranges. If the voltage is within this tolerance, it will pass it directly to the load. If outside this tolerance, it will use the inverter to boost (raise) the voltage to the appropriate level. If the input voltage decreases to a level the system can longer boost to the correct level, it will operate on batteries until the voltage is corrected or the batteries are exhausted.	The inverter is in parallel with the input voltage and interacts with it to raise or lower the voltages as necessary. If there is a sag, it will boost the voltage and if there is a swell it will buck the voltage, much like a line-interactive UPS system. If the input voltage becomes too low or high, the system will operate from batteries until the input returns to normal or the batteries are exhausted.	The ferroresonant transformer operates saturated, providing for inherent voltage regulation for both sags and swells. If the voltage falls outside UPS design setpoints, it will operate from batteries until input power returns to normal or the batteries are exhausted.