Electrical connector ratings: the pull-and-tug between emerging industry practices, safety, and the *NEC*

BY **STEVE TERRY**

ON THE SURFACE, the issue of electrical connector ratings in the entertainment industry would seem to fall into about the same interest category as watching paint dry—it doesn't seem very exciting, and it's hardly full of controversy. But the inexorable move to LED lighting systems and the associated upheaval in power distribution for entertainment facilities and portable power distribution systems is bringing up new issues in connector selection and use that are worth reviewing.

Background: connector ratings and configurations

Electrical connectors are everywhere in our personal and professional lives. They provide a critical element of convenience in our use of electrical power in a wide variety of applications. Every connector we use has one thing in common: an electrical rating. That rating provides at a minimum:

- The maximum *voltage* at which the connector is designed to safely operate
- The maximum *current* that can be safely carried by the connector

These two ratings insure that if the connector is used within its voltage and current rating, it will not present a fire or electrical shock hazard to property or personnel. Most often the ratings are verified by a third-party testing body, and will be covered in a Listing, Recognition, or other formal certification.

Separately from electrical ratings, a connector *may* also have a standardized physical configuration that is part of the Listing or certification. In North America, we know these configurations from the NEMA (National Association of Electrical Manufacturers) *Standard WD-6 Wiring Devices—Dimensional Specifications,* such as L5-20, 5-15, L21-20, etc. In some cases, we identify connector configurations directly by their ANSI standard, as in *ANSI E1.24 Dimensional Requirements for Stage Pin Connectors*. In other parts of the world, different standards bodies such as CENELEC and IEC develop connector configurations. This configuration serves a number of purposes:

- Guarantees that connectors of the same physical configuration from different manufacturers are dimensionally compatible and can be safely intermated.
- Assigns a standardized physical configuration to the electrical rating of the connector. This prevents connectors of different electrical ratings from being intermated.

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The combination of the electrical rating and the physical configuration provides a cornerstone of electrical safety: the expectation that if two connectors can be physically mated, there will be electrical compatibility between the power source and the device that is being connected to it. For instance, if a female 5-15 receptacle is encountered, there is a reasonable guarantee that it will be carrying 120 V at 15 A, as dictated by its electrical rating and its NEMA configuration. Likewise, if a 5-pole L21-20 locking-type connector is encountered, the reasonable guarantee means that it will be carrying a 208 Y/120 V three-phase, four-wire plus ground 20 A circuit, again dictated by its NEMA configuration. We take these reasonable guarantees for granted—indeed it's hard to imagine a safe electrical system without them.

Current entertainment industry practice

For the most part, entertainment industry use of connectors is compliant with codes and standards that support the reasonable guarantee outlined above. Unfortunately, there are notable exceptions, and perhaps more are on the way. First, it's important to note that not all connectors have standardized configurations tied to their electrical ratings. A notable example is the 19-pin "Socapex-type" connector now manufactured by a large number of companies. While these connectors have clear maximum voltage and current ratings, there is no standardized configuration for how the 19 pins of the device will be used. For many years, this was not an issue, since a *de facto* six-circuit configuration was adopted in the era of tungsten loads and dimmers. (See **Figure 1** for the 120 V connector pinout). But then an evolution occurred: in the touring and rental industry, automated luminaires that used constant rather than dimmed power began to appear. This did not present a problem in 230 V markets, but it was a different story in the 208 V/120 V North American market. Some automated luminaires of higher power now required 208 V branch circuits that were delta-connected phase-to-phase, instead of phase-to neutral as for 120 V circuits.

The result was a need for a portable power distribution system with 208 V branch circuits. This was accomplished via constant-power distribution units containing two-pole circuit breakers. Now there was a conundrum: What connectors and cables would be used to get these 208 V circuits into the rig? This decision did not remain open for long. Rental companies that owned thousands of six-circuit, 19-pin Socapex-type multicables simply made the decision: they would use these same multicables to carry 208 V branch circuits (see **Figure 1**—208 V connector pinout). A 208 V breakout would be provided with appropriate 208 V-rated female connectors used to mate with the 208 V automated luminaires.

But this created a problem: in the same rig, we now had female six-circuit Socapex-type connectors carrying 208 V branch circuits, along with the same connector carrying 120 V branch circuits. To add to the problem, neutral and phase conductors were assigned to the same connector pin depending on the application of the connector to 120 V circuits or 208 V circuits. These connectors are physically interchangeable, and thus intermatable. This situation was, and is, in direct violation of the *National Electrical Code*, which states:

> **406.4(F) Noninterchangeable Types.** Receptacles connected to circuits that have different voltages, frequencies, or types of current (ac or dc) on the same premises shall be of such

Connector Pin	Circuit	Function for six 120 V circuits in cable	Function for six 208 V circuits in cable
1	1	Hot	Hot L1
2	1	Neutral	Hot L2
3	2	Hot	Hot L1
4	2	Neutral	Hot L2
5	3	Hot	Hot L1
6	3	Neutral	Hot L2
7	4	Hot	Hot L1
8	4	Neutral	Lot L2
9	5	Hot	Hot L1
10	5	Neutral	Hot L2
11	6	Hot	Hot L1
12	6	Neutral	Hot L2
13	1	Equipment ground –typically pins 13-18 bussed	
14	2	Equipment ground –typically pins 13-18 bussed	
15	3	Equipment ground –typically pins 13-18 bussed	
16	4	Equipment ground –typically pins 13-18 bussed	
17	5	Equipment ground –typically pins 13-18 bussed	
18	6	Equipment ground –typically pins 13-18 bussed	
19	NC	Not used	

Figure 1—Typical 19-pin functions

Connector Pin	Circuit	Function for 6-208V circuits in cable "safe" method	
1	1	Hot Phase A	
2	2	Hot Phase A	
3	1	Hot Phase B	
4	2	Hot Phase B	
5	3	Hot Phase C	
6	4	Hot Phase C	
7	3	Hot Phase A	
8	4	Lot Phase A	
9	5	Hot Phase B	
10	6	Hot Phase B	
11	5	Hot Phase C	
12	6	Hot Phase C	
13	1	Equipment ground –typically pins 13-18 bussed	
14	2	Equipment ground –typically pins 13-18 bussed	
15	3	Equipment ground –typically pins 13-18 bussed	
16	4	Equipment ground –typically pins 13-18 bussed	
17	5	Equipment ground –typically pins 13-18 bussed	
18	6	Equipment ground –typically pins 13-18 bussed	
19	NC	Not used	

Figure 2—Alternate "safe" pinout for 208 V circuits

design that the attachment plugs used on these circuits are not interchangeable.

Efforts to correct this situation via hardware modifications or alternate benign pinouts were largely rejected by the industry. One example was a blocking pin in the unused pin 19 position that would have prevented 120 V breakouts from being plugged into female connectors carrying 208 V circuits. Another example was an alternate pinout which attempted to guarantee that 120 V circuit could never connect to 208 V when mis-plugged (see **Figure 2**—Alternate "safe" pinout for 208 V circuits). This alternate pinout approach created other problems:

1. Circuits in the cable are required to be on specific phases. This works with female connectors in power distribution racks that are directly and permanently connected to specific overcurrent protective devices on known phases. However, if the cable is connected to the distribution output via a patch panel or male breakout assembly, there is no longer a guarantee that specific circuits will be connected to specific phases. This condition makes the intended safety improvement of the alternate pinout fall apart.
2. Even if a power distribution unit or breakout assembly is marked "208 V," there is no standardized method of identifying the pinout of the connector. This means that power distribution racks, boxes, and breakouts from different companies may appear to be identical and can be intermated, but are in fact incompatible. In a world market where power distribution equipment and Socapex-type cable systems are often cross-rented and only assembled into a system by the end user, such hidden incompatible pinouts on intermatable connectors can create huge issues.

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Precise reasons for industry rejection of these schemes are unknown, but are presumed to be due to economics and the fact that the Authorities Having Jurisdiction (usually the electrical inspector) did not appear to object to the current situation. This is presumably because AHJs rarely look deeply inside portable touring rigs. The result is that during a load-in, one occasionally sees a bright flash accompanied by loud cursing when a 120 V breakout gets mis-plugged into a 208 V multicable, instantly burning out lamps on all six circuits.

The end result regarding Socapex-type six-circuit multicables is the loss of a reasonable guarantee of a known voltage on female receptacles of this type in a facility or portable distribution system. That is a system that in addition to violating the requirements of the *NEC*, also clearly requires qualified personnel to use the system safely.

The rise of LED luminaires and their effect on branch circuit connectors

As LED luminaires have proliferated in entertainment lighting systems, they have had a profound effect on connector usage and power distribution methods. Two important characteristics have driven these changes:

- LED luminaires typically operate at a fraction of the power of their tungsten counterparts. This makes it practical to daisy-chain the power feeds to multiple LED luminaires on a single branch circuit.
- LED luminaires often include universal power supplies that will operate from 100 V to 240 V—they are truly global products.

These characteristics have caused manufacturers to provide both a power input and power output connector on the luminaire. These connectors have typically been Neutrik powerCON or powerCON TRUE1 devices. It's worth taking a look at the characteristics of these connectors.

- Both powerCON and powerCON TRUE1 connectors are UL Recognized (not UL Listed) as Appliance Connectors. This means that they must be evaluated in the specific Listed piece of equipment where they are used, in this case the luminaire. This insures that the connectors are applied within their Conditions of Use.
- Neither powerCON nor powerCON TRUE1 are rated as General Purpose Connectors suitable for field installation on branch circuit wiring. In addition, powerCON is not rated for make and break under load, while powerCON TRUE 1 is rated for make and break under load.
- Neither powerCON nor powerCON TRUE1 are designed to a configuration standard that defines their mechanical dimensions and their electrical rating.
- powerCON and powerCON TRUE1 both have a voltage rating of 250 V, but are regularly used at a wide variety of worldwide voltages from 100 V to 240 V with neutral-hot-ground or hot-hot-ground connections, depending on voltage and geography.

Conclusion

Socapex-type six-circuit connectors, Neutrik powerCon, and powerCon TRUE1 connectors have become entertainment industry world-wide *de facto* standards for power distribution. By virtue of sheer numbers, the industry is unlikely to change to different connectors in the foreseeable future. These connectors share one thing in common: they lack a configuration standard that dictates pinout assignment and connector voltage on intermatable connectors. Because they are used at different voltages and connector pinouts—often within the same system—the *possibility* exists for safety hazards or misuse of these devices, leaving aside violations of the *NEC*.

Why hasn't the possibility of a hazard turned into real problems in the entertainment industry? Many hundreds of thousands of these connectors have been in safe use for many years in the entertainment industry—without causing injury or damage to property. There is a reason for this: precisely because they are not *general-purpose* connectors, they are used by qualified, and probably certified, personnel who understand the requirements for setting up and assembling systems that use these connectors. Basic tools such as marking of connectors with the voltage they carry are used by these qualified personnel to prevent potential hazards from turning into serious problems. The *NEC* definition of a qualified person provides an appropriate conclusion to this discussion:

Qualified Person. One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.

We already have one notable example of a connector system in the entertainment industry where use by qualified personnel is mandated by the *NEC*: single-pole separable connectors in portable feeder applications. It would be reasonable to extend the qualified personnel requirement to the uses of branch circuit connectors outlined above, where no standard configuration exists for those connectors. Finally, identification of electrically qualified personnel in our industry has become a lot easier and unequivocal over the last 10 years due to the ETCP Entertainment Electrician and Portable Power Distribution Technician certifications. ■

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