AC POWER DISTRIBUTION

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Revision one October 1998
" " two January 2001
" " three December 2009

When you are specifying equipment for a large installation such as a church, nightclub, or recording studio, you should also include recommendations for a proper electrical power distribution system for that installation. If you ignore the electrical system, it is very likely you will be spending more time in the future trying to solve ground loop and EMI interference problems. More often the time spent running down these gremlins is beyond that which you estimated as labor time for the installation. If everything is taken care of up front, then everyone benefits.

I started working with electronics as a means of making a living thirty-two years ago. I have been involved in audio for sound reinforcement for twenty-six years with six years in communications electronics and process control electronics before that. I have come to learn many tricks (which aren't really tricks at all) to overcome ground loops and other interference problems in audio systems.

You can put the audio system on a dedicated, isolated electrical service with its own power transformer. You can even establish a "Star" ground, an AWG #000 ground buss, or even a separate technical ground on the electrical service system to the audio equipment, but doing any or all of these will only solve a few of the problems that can prevent your customer's absolute satisfaction with the installation.

I have known for some time that if you can absolutely balance the power distribution system, you can eliminate the source of your problems. It is impossible to control what other electrical equipment is placed on the rest of the building's electrical power distribution service. Even if you could control this situation, you would not eliminate all of the sources of possible contributions to hum and noise problems. Read on to learn more.

The conventional method of power distribution in the U.S.A. according to the NEC (National Electrical Code) is just not the best that it can be for our increasingly sophisticated audio applications. The standard electrical system is based on a 240-volt AC service feed from the transformer on the electrical utility pole outside the building. At the building's main electrical service panel-box, the 240-volt service is split into two circuit paths of 120-volts each.

This is accomplished because there are three wires feeding the main electrical service panel from the transformer on the power pole, the third wire being a center tap of the 240-volt secondary of the power transformer. At the building's electrical service panel, this third wire center tap from the 240-volt secondary of the power transformer on the pole is connected or in electricians language, "bonded" to the neutral wire and the building's electrical system's service ground. We distribute two legs (circuits) of 120-volts each throughout the building (It is not correct to refer to this as a two-phase system, because it is actually two legs of the same electrical phase).

These two legs are L1 & L2 (for Leg 1 and Leg 2). L 1 is Hot (Black) and the Neutral wire (White) make up one leg of service, and L2 Hot (Red) and the white Neutral make up the second electrical power service leg. Note that both 120-volt circuit paths share the common Neutral. If we do have a 240-volt appliance such as an electrical stove, hot water heater, clothes dryer, etc., then the 240-volts is obtained by using the two hot leads L1 (Black) and L2 (Red).

In an ideal world there would never be more current drawn by one leg of the electrical distribution system than drawn by the other circuit leg. Since we are not in an ideal world and have no control over what is plugged into each power leg throughout the building, we have no way to insure that the distribution of the power between legs L1 & L2 is balanced. Some of our problems can be, and are, caused by compressors, motors, and other equipment in the building that have different current demands over time.

But in installations where we are using lots of audio equipment and drawing significant amounts of current, it is the power line filter capacitors and grounding schemes used in the audio equipment itself that lead to problems. There are things to do in theory because sometimes all of the best tricks can't totally eliminate the noise problem (See the article on Hum & Pin #1). We can minimize the problems at the time of installation, but what happens six months down the road when we are not there and the customer decides to hook up some newly acquired piece of gear?

The best thing we can do for the customer is to specify a balanced AC electrical service system. I prefer to call this a balanced electrical service because that is what it actually is, not a "two phase" system, as some call it. The way in which this balanced distribution is accomplished is; instead of a hot lead wire with a potential of 120-volts referenced to a grounded neutral, we actually provide two hot lead wires of 60 volts each. How do we do this? By specifying an electrical power transformer that has a 120-Volt secondary with a center transformer tap.

If the customer's electrical contractor can install one of these available center tapped power transformers and connect the center tap to the normal ground buss, we then end up with a transformer isolated balanced service that can provide a center tapped 120-volt secondary, so we will then have 60-volts on each of two hot AC legs.

What was previously known as the Neutral wire (White) is now the other 60-volt Hot wire. What was previously known as the ground wire (Green) is now still the system ground. This common ground wire return to the electrical panel is also connected to the center tap of the 120-volt secondary of the new transformer, which is also connected to a bonded ground in this audio system's dedicated electrical service panel. Once again, both wires are hot with 60-volts of potential between the white wire and ground (green) and 60-volts between the black wire and ground, which results in 120 volts between the white and black wires (60 + 60 = 120).

Of course now each hot leg <u>must</u> include a circuit breaker. You must use double pole circuit breakers in the service panel for each circuit because you now have two hot voltage legs. If the entire 120-volt circuit draws 20 amperes of current, then each hot leg (L1 & L2) will each have a 20-amp circuit breaker. The system is still grounded in the conventional manner but this is best done via a <u>separate</u> technical ground from the normal main electrical service.

Power transformers are rated in KVA (Kilo-Volt-Amp). Electrical power equals the electrical potential, or pressure, measured in volts times the rate of electrical current flow measured in amperes. In audio we measure power in watts: 2000 watts would have a KVA rating of 2 KVA.

I recommend that the electrical contractor obtain the orange iso-system duplex AC outlets like the ones that are used in hospitals to identify those outlets that are on the isolated balanced electrical distribution. Remember everything that is connected to the audio system needs to be powered from the balanced distribution system. This includes tape and DAT recorders, CD players, video recorders, and cameras.

In the past this approach to electrical power distribution was not covered in the NEC code, if installed correctly, it did not go against or violate the NEC code. It just wasn't covered, and it may have taken some explaining to a local inspector as to why all of this is necessary.

The beauty of this approach is that everything (audio or video wise) that you plug into this isolated circuit will be balanced as far as the current between chassis ground and the two 60 volt hot leads. There will be no voltages between the chassis of any two pieces of equipment plugged into this system. You have eliminated the cause of your troubles at the source. You have transformer isolation between your audio electrical system and any other electrical equipment in the building.

Commercial Power or 208 Three Phase

In large buildings such as Hotels, Theaters, and some Churches, there is what is referred to as commercial power or a power system that is based on three distinct phase legs of 208 Volts each. Each phase leg is sourced from a transformer system that provides a difference of 120 degrees in electrical phase. Why is this necessary? Mainly because single phase electrical become very inefficient when trying to drive the very large motors that you will find in industry and commercial buildings. These facilities employ large industrial motors that actually have three separate motor windings. Each of the three windings is wired to one of the three electrical power phases.

This method provides for much more torque when trying to move the very large mass of the armatures of these industrial size motors. With single phase, the peak turning energy or torque occurs twice, at the peak of each of the 60 Hertz cycles, or 120 times a second . 3 phase electrical power provides a peak energy torque twice every 120 degrees, which means that 360 times a second we are obtaining peak torque energy from the distribution system. Simply put we can turn more massive motors more easily and efficiently.

However 208 three phase causes audio systems the most problems. Why? Because the 120 Volts necessary to drive ordinary electronic equipment is derived from the 208 volt distribution system. It is not important to understand how this is done, but essentially two of the three phase legs are combined together. Now most people would think that 208 volts combined with 208 volts, would result in 416 volts, but not so. Since they are two separate phases that are separated by 120 degrees, they do not add together. The math involves cosines of the phase angle, but the result is that we end up with less voltage or 120 Volts.

When we hook up audio equipment in a building that has the 120 volts required, derived from a 208 volt three phase system, we are faced with more than a 60 Hz ground loop, we end up with 60, 120, and 180 Hz ground currents, that get into the audio system. Even then, best practiced grounding

schemes can only reduce the noise in the system. The only way to get the cleanest power in these (208 3-phase) systems is to go with a balanced power scheme. This is where the electrical power distribution engineer comes in. Transformers can be added to isolate the audio electrical distribution system from the rest of the buildings 3-phase system.

Licensed electricians and electrical contractors are the only people that are qualified to install the types of system discussed above.

Give me a call if you have any questions or comments.

Since I first wrote this article this method for a balanced power distribution system has been written into the 1996 National Electrical Code (NEC) under Article 530 Part "G."

So there is no excuse for not employing this method when circumstances require absolute clean power. There are companies that now offer turnkey systems consisting of the transformers, electrical panel, and circuit breakers.