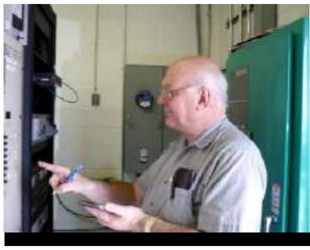

The

Broadcasters' Desktop Resource

www.theBDR.net ... *edited by Barry Mishkind – the Eclectic Engineer*

From the Transmitter Site

Three-phase vs Single-phase Power: A discussion

Compiled by Randy Henry

[October 2010] Sometimes a discussion on an Internet mailing list can range far and wide, leaving a lot of opinions (we all have them, right?), but often as the discussion proceeds different ways of looking at a problem may provide alternate solutions.

In September 2010 a discussion on the BROADCAST mailing list [BC] www.radiolists.net which started with a question about cost of electrical service led to a number of concerns and tips regarding installations.

I have compiled what I thought were the key comments.

Main Topic: **Three-phase or Single-phase**
Secondary Topic: **Safety regarding transmitter site AC service**

An opening thread asked if spending $10k for three-phase power or single-phase at no installation cost was worth it. FPL (Florida Power and Light) told the FM licensee that it did not offer Closed Delta service, only 120/208 Wye. The facility is about 300 feet from three-phase power poles and would use 20 kVA.

The thread became very educational regarding three-phase vs. single-phase, power company issues, safety, and grounding in a three-phase environment. I hope you will find it useful.

Kyle Magrill suggests single-phase in the situation

Most transmitters made within the last 20 to 30 years came in either single or three-phase models. Most of those can be adapted in the field for the other type of power. Efficiency-wise there's a slight theoretical gain for three-phase, but all of the manufacturers that I've spoken to have said it's negligible.

Further, the economies of scale make it cheaper to make single-phase units, so the lower purchase price tends to offset any savings gain. Then there's the discussion of Closed Delta vs Wye or Open Delta. Most of the old timers will tell you that a Closed Delta is the preference, followed distantly by a Wye and never, ever an Open Delta. Of course, the power company hates Closed Deltas because it requires an extra wire.

I saw an engineer in Miami try to get FPL to provide a Closed Delta to his new transmitter site and they flatly refused. Finally, in desperation, he put the FPL manager on a conference call with a Harris engineer. The Harris guy told the FPL man that Harris would not cover the transmitter's warranty unless it was connected to a Closed Delta and that Harris would join the radio station is suing FPL if any lightning damage was done to the transmitter's power circuits. FPL gave in and supplied the Closed Delta.

So, considering the difficulty in getting good three-phase, the question is: can your site get by with single-phase? If so, then that's probably a perfectly acceptable option rather than forking out $10k for three-phase that might not really help you.

<u>Mike McCarthy</u> is 50/50

I have a site which is much the same TX power level and we have three-phase. BUT it's running the 200A service with a simple break panel at the edge of safe limits.

Based on my experience, it's a 50/50 roll of the dice. More and more equipment at that power level is going single-phase. But you WILL need 600 Amp service with two 10 kW boxes and HVAC for single-phase as opposed to a less costly and more readily available 400 Amp three-phase panelboard.

I would suggest installing a 400 Amp three-phase panelboard (as opposed to using a standard main disconnect, breaker panel and circuit breakers.) The panelboard then incorporates safety switches for power control of the TX's and HVAC's directly. A substantial safety factor cost savings. Panelboards are also service rated (YES...EVEN IN CHICAGO). Thus you don't need a fused/breakered service disconnect prior to it. The fused disconnect switches in the panelboard are technically the "service disconnects" for each major piece piece of equipment and of the small load center/breaker panel. Another savings.

They tend to be heavier and more resistant to surge damage. We just did that at a site where the whole site is on the genset and only the fused 400 service disconnect precedes the ATS...which is required by code. But it incorporates a panel board and that satisfies the code for over-current protection of the genset service.

We also just completed an 800 A single-phase service using a panel board for another site since three-phase was an insane amount to bring in to the site.

What is the cost differential between the associated hardware and labor to install the much larger single-phase than the smaller three-phase?

There are a number of other issues as well. Such as you increase the risk to loss of electric service by a factor of three when you opt for three-phase. Reason...? Instead of one conductor on the pole being needed, you need all three for the three-phase equipment to operate.

Also, look at the cost per kW/hr between the two services. Some utilities have a different tariff for the two services.

And finally, consider the single-phase loads. Will you create an imbalance which will draw a substantial differential between phases or create more than 20% neutral current flow. If so, you might have an issue with "wasted" power.

When you get past 200 A, there are a number of ways to create "services"... safely and entirely within the code. And the most economical as well as safe is to use panel boards.

Tom Taggart gives three reasons for single-phase

1. You said you already have a single-phase transmitter that will work – so dollars saved there;

2. Don't know about FPL, but Allegheny Elec. here is a third world company, has been getting worse. With industry trends like this, keep it simple, less to go wrong or break;

3. Eventually you will get a new transmitter, which will probably be solid state and single-phase. Why build a complicated plant when you don't have to?

Peter Haas responds to **Kyle Magrill**

> *Most of the old timers will tell you that a Closed Delta is the preference, followed distantly by a Wye and never, ever and Open Delta.*

120/240 Closed Delta and 120/208 Wye are equal in three-phase carrying capacity, but 120/240 Closed Delta is only 2/3 of 120/208 Wye in single-phase capacity as the so-called "high-leg" may never be used for single-phase loads.

Depending upon local conditions, Delta services, for commercial/industrial customers, are becoming obsolete. In the under 300 Volt class, 120/208 Wye is becoming more popular. In the over 300 Volt but under 600 Volt class, 277/480 Wye is quickly displacing 480 Closed Delta.

> *Of course, the power company hates Closed Deltas because it requires an extra wire.*

Nope, it still requires three current-carrying wires (plus a ground wire).

What Open Delta doesn't require is a third distribution transformer, the absence of which derives most of the utility savings (a capital account cost), and the absence of which derives most of the customer problems (an expense account cost).

Either you pay up-front (on the capital side), or you may (probably will) pay later (on the expense side).

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Harris refuses to honor its warranty if the service is not Closed Delta or Wye (most cases) or 277/480 Wye (high-power cases).

Indeed, on one 50 kW installation for which I acted in a consulting capacity, Harris even refused to honor its warranty if a so-called "T transformer" was used as the distribution transformer. (A T-transformer is nothing more than two transformer components within the same housing, connected in a modified "Scott T" configuration.)

Normally seen in older installations, where these may be found converting a new utility three-phase feeder to an old two-phase customer, or an old two-phase feeder to a new three-phase customer, a T-transformer can also accomplish three-phase to three-phase conversions.

When connected for three-phase to three-phase, the per-unit impedances of the three legs are not the same. Hence, why Harris refused to honor the warranty on the new 3DX-50 if a conventional three-phase transformer was not used. In such a conventional transformer, the per-unit impedances is the same on all three legs.

As a consequence, the utility's T-transformer had to be pulled out, and a concrete pad and housing had to be constructed for the conventional three-phase transformer.

When a T-transformer is used, the primary side is always connected as Delta even if the feeder is Wye (the primary side must be ungrounded); the secondary side may be Delta or Wye. A neutral is available if Wye.

Peter Haas responds to Mike McCarthy

> *Panelboards are also service rated (YES...EVEN IN CHICAGO). Thus you don't need a fused/breakered service disconnect prior to it. The fused disconnect switches in the panelboard are technically the "service disconnects" for each major piece piece of equipment and of the small load center/breaker panel. Another savings....*

While technically correct, I would strongly recommend installing a fusible safety switch between the panelboard and each transmitter.

The safety switch should be arranged to interrupt all transmitter power. A lock-out/tag-out device should be available for every safety switch. The breaker in the panelboard is intended to protect the feeder, only. Other protection (including operator protection) must be provided for by additional apparatus, hence the safety switch.

It is indeed possible to apply accessories to some breakers to achieve lock-out/tag-out, but a safety switch within eyesight and easy access of the transmitter has much to recommend it.

Peter Haas re-emphasizes the need for safety

I cannot overemphasize the importance of a fusible safety switch for each transmitter, and for that switch to interrupt all transmitter power.

How many times has the three-phase panelboard breaker (usually high-capacity) been turned OFF, yet the single-phase breaker which supplies convenience outlet power, or control power (usually small-capacity) remained turned ON?

In cases of an ill-designed transmitter, utility outlet power or control power may be derived from two of the three-phases of the load side of the safety switch, using a small "dry-type" transformer.

In this case, operator or emergency personnel can be assured that a locked-out switch does indeed guarantee a "dead" box.

Peter Haas addresses power company and three-phase intricacies

[There are] Reasons why the primary (high) side of a distribution transformer may be ungrounded. At the large municipal utility (this Nation's largest) where I was an EE in an earlier lifetime, all our primary systems and all our secondary systems, too, were Delta, hence were ungrounded.

Our transmission system was among the largest in the World. Certainly among the largest in North America: 500 kV AC, also 287.5 kV, 230 kV, 138 kV, and some 115 kV AC. Also 1000 kV DC. Our distribution system was the largest of the municipals, with 34.5 kV and 4.8 kV distribution to utility or customer substations.

Most customers were on our 4.8 kV system, which is not too impressive by contemporary standards, but we had more than 130 distribution stations within the city alone (we did not normally distribute outside the city).

Commercial/industrial customers of 1000 kVA or more would be supplied by our 34.5 kV system.

No customers were on our transmission system, only other municipals or "investor-owned" utilities, on order to maintain exceptionally high reliability (about ten times as reliable as our "investor-owned" interchange partners).

In a Delta system, there can be no "zero-sequence" currents.

Additionally, a Delta system can accept a temporary line-to-ground fault, and yet it can still deliver three-phase power without interruption. No grounded system can make the same claim.

So, that is the complete answer: a Delta system can accept a temporary line-to-ground fault, and can still deliver three-phase power; no grounded system can.

"Zero-sequence" is one of the three so-called "symmetrical components" which were used to describe unbalanced three-phase systems.

The others were "positive-sequence" and "negative-sequence".

The Wiki is of historical interest http://en.wikipedia.org/wiki/Symmetrical_components

As a practical matter, my division within my employer's organization pioneered other methods of the analysis and design of three-phase power generation, transmission and distribution systems, including new and novel computer-based methods which were later adopted by others.

We routinely simulated, on a steady-state and a transient basis, the so-called Western System (Canada to Mexico; the Rocky Mountains to the Pacific Ocean), which system we designed.

The other extant systems are the Texas System and the Eastern System.

Chris Gebhardt responds to Peter Haas – further safety cautions

> *I cannot overemphasize the importance of a fusible safety switch for each transmitter, and for that switch to interrupt all transmitter power. In this case, operator or emergency personnel can be assured that a locked-out switch does indeed guarantee a "dead" box.*

This is good advice. However, at the risk of a bit of thread drift but in the spirit of safety, I'd like to pass one thing along. Always, ALWAYS check with your meter before you start sticking hands and/or tools in.

We did a hot-swap on a 100kva UPS last week that involved back-feeding a 208VAC distribution panel via a standby 480-208VAC step-down transformer. The idea was to completely pull the UPS out, prep the space for the new UPS, install then turn up all without dropping the load. Mission accomplished, but with so many opportunities to go boom you better believe we measured EVERYTHING twice before touching.

This is especially true when dealing with anything that may have capacitance. Make sure you wait for or (safely) induce discharge.

Grady Moates responds to Peter Haas

> *Additionally, a Delta system can accept a temporary line-to-ground fault, and yet it can still deliver three-phase power without interruption. No grounded system can make the same claim. So, that is the complete answer: a Delta system can accept a temporary line-to-ground fault, and can still deliver three-phase power; no grounded system can.*

I can testify to this. . . a site I work at recently had a ground fault in one of the three 8 kV phases of the 13.8 kV three-phase primary feed to the building. It was a buried service running past towers one and two of a five-tower in-line array. They had to TDR it and dig. So, the utility supplier had a rental company bring in a genset. When they fired it up, literally the fire went up! The outside wall of the transmitter building lit up like a fireworks display! It was so bright that, with my back turned to the building, the chain link fence and the trees 50 feet away lit up like it was daytime.

The genset guy was clueless, so I got out my trusty Fluke and started doing some simple troubleshooting. I found a ground on one of the three-phases of the 480-Volt secondary system. When I opened up the disconnect switches before and after the utility meter, the ground was between the two switches. . . the only things in that portion of the system were a couple of pipe nipples, the meter-jack box, the meter and the jack.

After a little more noodling around, I found that the center conductor through the meter jack had a grounding tab installed on it that was hard to see underneath the 4/0 copper wire that connected to that terminal. On the grounding tab was a small tag that said something like "remove for three-phase service".

That grounding tab had been there for 9 years, ever since the service for that transmitter had been installed. The three-phase 480 Delta service had tolerated it all that time.

Peter Haas responds to Grady Moates

On Sep 27, 2010, at 9:03 PM, Grady Moates wrote:

> *After a little more noodling around, I found that the center conductor through the meter jack had a grounding tab installed on it that was hard to see underneath the 4/0 copper wire that connected to that terminal. On the grounding tab was a small tag that said something like "remove for three-phase service". That grounding tab had been there for 9 years, ever since the service for that transmitter had been installed. The three-phase 480 Delta service had tolerated it all that time.*

That 480 three-phase system was ... unintentionally ... simulating a "corner-grounded Delta" one of the obsolete systems because it requires special breakers for proper protection.

The code has had this language for quite a few years, "... so-called 'Delta breakers' are not permitted ...", but, of course, this applies to NEW systems, not to "old work" systems.

However, that unintentional corner-ground was an accident waiting to happen ... and it did. We used to allow 240 and 480 corner-grounded three-phase services as it was more economical for the customer.

Essentially, this allows you to use a common two-bus panelboard for controlling and protecting three-phase loads. All you have to do is install a second grounding bar kit and that becomes your B-phase and which is never switched.

Corner-grounded is also called "grounded B phase", although that is probably a poor term as the most common three-phase service is 120/240 Delta, with three isolated buses where A-N and C-N are 120 single-phase, A-C is 240 single-phase and A-B-C is 240 three-phase, and, of course, N is at ground potential, but it is not a grounding conductor, G is.

Barry Mishkind recalls when a phase got wired to ground

I lost a discussion with the GM of a station some years back. They were expanding the electrical service to accommodate a new transmitter. I wanted them to do it after hours, but to save a few bucks, the GM arranged for the electrician to come at 12:00 Noon.

After being off the air for about a half an hour, it was time to transfer the power. The switches were thrown and after the explosion, it was clear they had wired one of the phases directly to ground.

Four hours or so later, after PM drive, the station got back on the air. I'm not sure they saved any money on that deal.

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