Three Phase Transformer Connections

We receive many member requests for 3 phase service. This may be as much as they know until an engineer or electrician gets involved with the project. Single phase service is provided by one transformer with a secondary voltage of 120V, 120/240V or 240/480V. There are many more options for serving 3 phase loads. The different options are listed below.

1. 120/240V Delta three phase with two transformers
2. 120/240V Delta three phase with three transformers
3. 120/208V Y three phase (this configuration requires three transformers)
4. 120/208V Y three phase with pad-mounted transformer
5. 240/480V Delta three phase with two transformers
6. 480V Delta three phase with two transformers
7. 240/480V Delta three phase with three transformers
8. 480V Delta three phase with three transformers
9. 277/480V Y three phase (this configuration requires three transformers)
10. 277/480V Y three phase with pad-mounted transformer
11. 2400V Delta three phase
12. 2400/4160V Y three phase

Each option will be explained in more detail including pictures on the following pages.

There are many valid reasons that a member would request three phase service. The member will be required to complete the Electric Load Requirements Form or provide comparable information for each three phase request. This provides documentation from the member for the voltage. It also provides Tri-County information to size transformers, service and meter.

A few members and electricians have the mistaken idea that three phase service is cheaper than single phase service. This is based on the idea that the nameplate current rating for a three phase device will be about a third of the nameplate current rating for a single phase device. However, we meter energy (voltage x amps) instead of current (amps). A single phase device with the same rating as a three phase device will use the same energy. For example, a 5HP single phase motor will use the same energy as a 5HP three phase motor assuming they perform the same function and have the same efficiency.
1. 120/240V Delta Three Phase with Two Transformers

This is a very common configuration for service to small three phase loads. It is usually called “V” phase or “B” phase installation. The “V” phase terminology comes from the normal Y configuration for our distribution system. When only two transformers are used, it is an “Open Y” configuration on the primary side. Since the “Y” reflects the phase-to-ground contribution from three transformers, leave the bottom part of the “Y” off and a “V” is left with two transformers. The “B” phase terminology probably comes from REA construction standards. Two phase pole top assemblies are “B” units.

The secondary side is connected in an “Open Delta” configuration. This is a 4-wire service and the member receives three phase service. The voltage from any phase to another phase is 240V. Single phase power is provided from a 120/240V single phase center-tapped transformer. This transformer is called the lighting transformer. The other transformer is called the power transformer. No single phase load is connected to the power transformer. The neutral is connected to the center tap on the lighting transformer. The voltage is 120V from the neutral to the outside taps on the lighting transformer. The voltage from the neutral to the third phase is undefined. This is the infamous “wild leg” and is typically 208V. It may also be called a “freak leg”.

Recognizing this installation in the field is the easiest since this is the only way to hook up two transformers. You will not be able to determine if the secondary voltage is 120/240V or 240/480V. You will be able to determine if it is 480V straight power because neither transformer will be center-tapped.

The drawing at right shows the voltage diagram for the secondary side. A 240/480V installation with two transformers will look similar. A 480V straight power installation will not use the center tap connection.

The primary side is connected in an “Open Wye” configuration. This type of installation is often termed an “Open Wye-Open Delta” transformation. It is normally used where the largest motor is 20hp or less. This is just a guideline since 25 and 30hp motors will work with an Open Wye-Open Delta configuration. Submersible pumps can cause problems since they have a higher current draw than other motors and tend to be sized closer to capacity. This installation should also be limited to a total load of 50-75kW.

The lighting transformer serves the entire single phase load. It also serves 58% of the three phase load. The power transformer also serves 58% of the three phase load. Note that the total percentage of three phase load from both transformers adds up to more than
100%. Since the lighting transformer serves the single phase load in addition to part of the three phase load, it is usually larger than the power transformer.

The drawing at right shows a typical wiring configuration. The transformer on the left is the lighting transformer. It is the one with the center bushing (x2) tied to the neutral. The transformer on the right is the power transformer. The center bushing is not used. Note that two bushings (x1 on the left transformer and x3 on the right transformer) are tied together. Together they serve one phase (b in this drawing). Also note that the neutral to c phase voltage is 208V. In actual situations, the measured voltage may be 216-217V instead of 208V. This is the wild leg since c phase is served by the power transformer.

The picture below shows a typical installation without a transformer bracket. In this case the right transformer is the lighting transformer. Two clues are used to tell you that information. The first is the size. The right transformer is larger (size and capacity). The second is the center bushing is connected to the neutral. The center bushing on the left transformer is not used.
A transformer bracket is used for most installations today. The picture above shows an Open Wye/Open Delta bank mounted on the transformer bracket. Clearly visible is the location to mount the third transformer if needed. When installed on a three phase line, it is common to connect the transformers to the outside phases.
2. 120/240V Delta Three Phase with Three Transformers

This transformer configuration is used when the Open Wye-Open Delta configuration is not adequate. It is known as a Wye-Delta configuration. It is no longer open since three transformers are used instead of two. The secondary side is connected in a Delta configuration. This is a 4-wire service and the member receives three phase service. The voltage from any phase to another phase is 240V. Single phase power is provided from a 120/240V single phase center-tapped transformer. This transformer is called the lighting transformer. The other two transformers are called the power transformer. No single phase load is connected to the power transformers. The neutral is connected to the center bushing on the lighting transformer. The voltage is 120V from the neutral to the outside taps on the lighting transformer. The voltage from the neutral to the third phase is undefined. This again is the “wild leg” or “freak leg” and is typically 208V.

The drawing at right shows the voltage diagram for the secondary side. A 240/480V installation with two transformers will look similar. A 480V straight power installation will not use the center tap connection.

The lighting transformer should be sized to serve 2/3 of the single phase load and 1/3 of the three phase load. The two power transformers should be sized to serve 1/3 of the single phase load and 1/3 of the three phase load. It shows that this configuration is not efficient as the Wye-Wye configuration (option 3 from the list on Page 1) since the total transformer bank must be sized for 133% of the single phase load (2/3 + 1/3 + 1/3 = 1.33). It also has two other disadvantages over a Wye-Wye configuration.

One disadvantage is feedback on the primary side when a primary phase is lost. The three transformers in this configuration form a closed loop on the secondary side. When a primary phase is lost, the closed delta configuration will induce a voltage on the primary side. This can cause problems with restoration and must be remembered by the serviceman. The induced voltage does not happen with an Open Wye-Open Delta configuration since the secondary side does not have a closed loop. The induced voltage does not happen with a Wye-Wye configuration since the secondary side is configured Wye instead of Delta.

A second disadvantage is ferroresonance. Ferroresonance is an occurrence of a non-stable high voltage set up due to the magnetizing impedance of the transformers matching the capacitance of the circuit under no-load or low load conditions. It occurs when a fuse is blown, a wire is broken or during single phase switching on a transformer with Delta
connections on the low side or the high side. Ferroresonance can cause damage from over-voltage and will usually cause a noticeable vibration in the transformers. The problem can be mitigated when all three phases are energized at the same time. It is also mitigated by energizing the transformer under load or grounding the H2 bushing on the all three transformers on a temporary basis. Ferroresonance will not happen in an Open Wye-Open Delta configuration. It is very unlikely to occur in a Wye-Wye configuration. Neither has the closed secondary loop in the Wye-Delta configuration.

The drawing at right shows a typical wiring configuration. The transformer in the middle is the lighting transformer. It is the one with the center bushing (x2) tied to the neutral. It is normally the middle transformer on the pole. The other two transformers are the power transformers. The center bushing is not used on these two. Note are two bushings (x1 on the left transformer and x3 on the right transformer) are tied together on adjacent transformers. Together they serve one phase. This is the way to determine if a three phase bank is Wye-Delta configuration instead of a Wye-Wye. Also note that the neutral to c phase voltage is 208V. This is the wild leg since c phase is served by the power transformers.

The picture below shows a typical installation. The middle transformer is a 50kVA while the other two are 37.5kVA. This is normal that the middle transformer be one size larger than the other two. Note the jumper tying adjacent secondary bushings together. This is characteristic of a delta installation.
3. 120/208V Y Three Phase

This is a very common configuration for larger three phase loads. It is widely used in retail and office applications. This is a four wire service and the member receives three phase service. The voltage from any phase to another phase is 208V. This is different than the 240V between any two phases on a delta service. Many (maybe most) three phase motors have taps that allow them to be set for 208V or 240V. Those that do not have taps will be set for 220V and can handle either voltage. Single phase power is only 120V and is served from each transformer. For this reason the panel should be wired to serve single phase load evenly from each phase.

The drawing at right shows the voltage diagram for the secondary side. A 277/480V installation will look similar.

The primary side is also connected Wye. This type of installation is often termed a Wye-Wye transformation. It is preferred over a 120/240V Wye-Delta configuration for the reasons stated in the previous section.

Each transformer carries 1/3 of the single phase load and 1/3 of the three phase load. Stated another way, each transformer serves 1/3 of the total load.

The drawing at right shows a typical wiring configuration. The secondary windings inside the transformer have to be changed. The lead windings are “cut over”. This is the process of moving the lead from the x2 bushing to either x1 or x3 as appropriate. When complete, the transformer has both windings connected from x1 to x3 (the two are in parallel). The voltage from x1 to x3 is now 120V. Note how the x2 bushing is not used on any transformer. In this drawing the x3 bushing on each transformer is tied to the neutral. Each x1 bushing provides one of the phases. Adjacent bushings are not tied together like they are in a Delta configuration.

The picture below shows a typical installation. There are three 100kVA transformers. They do not have a center bushing. Transformers purchased for 120/208V or 277/480V will not have a center bushing. This is one easy spotting feature of this type of
transformer bank. The left bushing on each transformer is tied together and to the neutral. Each right bushing serves a phase.
4. 120/208V Y Three Phase with Pad-Mounted Transformers

This is a common application to serve three phase loads where a pad-mounted transformer is desired or needed. This is a four wire service and the member receives three phase service. The voltage from any phase to another phase is 208V. The size and secondary voltage is typically painted on the cabinet face. The voltage diagram is identical to the 120/208V diagram in the previous section. The typical transformer sizes are 112kVA, 225kVA, 300kVA, 500kVA, 750kVA, and 1000kVA. It is possible to get 45kVA and 75kVA transformers but they are not as common because the cost is similar to the 112kVA transformer. Above 1000kVA, pad-mounted transformers will have a higher secondary voltage such as 277/480V. In practice, it is uncommon to use a transformer larger than 300kVA for a 120/208V service.

We have two standard pad sizes for a pad-mounted transformer. Up to a 500kVA pad-mounted transformer, an 8 foot x 8 foot pad is used. For a 750kVA to 2500kVA pad-mounted transformer, a 10 foot x 10 foot pad is used. Typically, the member or construction company is requested to provide the pad. They are already pouring concrete for the slab and flat work such as drives and sidewalks. A diagram of the pad needs to be provided to the construction crews.

The metering can be installed on the cabinet of the transformer if the service is for only one member. Current transformers (CT’s) will be placed around the secondary bushings. Control cable connects the CT’s to the meter. If multiple meters are needed such as at a shopping center, then the metering will be installed on the building.

The member will be responsible for the installation of the service from the secondary lugs of the transformer to the building. The pad diagram shows the opening for the secondary side. The member will need this information to determine the number and size of conduits that need to be installed between the transformer and the building.

Clearances need to be considered in the design process. Ten feet of clearance needs to be maintained in front of the access doors for working clearance. The distance will allow a man to use a hot stick when working on the connections in the primary cabinet. The distance from the transformer to the building wall requires a minimum of 12 feet if the building wall is anything less than a 3 hour fire rating. See the drawing below for other clearance requirements.
The drawing above shows a typical pad-mounted transformer. Looking at the Front View, the primary side is on the left and the secondary side is on the right. The meter would be mounted on the right side of the transformer. The HV & LV Detail show the typical locations of the primary bushings (H1, H2, and H3 – circle 9). It also shows the typical locations of the secondary bushings (X1, X2, and X3 – circle 10). The transformer nameplate is located in the secondary side.
5. 240/480V Delta Three Phase with Two Transformers

This installation is very similar to the 120/240V Delta Three Phase with Two Transformers. See Section 1 for a more complete description.
6. 480V Delta Three Phase with Two Transformers

This installation is also very similar to the 120/240V Delta Three Phase with Two Transformers. One big difference is the lack of a center tap transformer. This is a 3 wire 3 phase service. The voltage between any two wires is 480V. Phase-to-ground voltage does not make sense. One phase will be grounded. It is to be used where only three phase service is needed. No single phase service is provided.

Triplex wire and a single phase meter based are used. The member will usually request a 100A service. Typically the load will pull less than 20A per phase. The member needs to use a 200A meter base. The 200A meter base provides more working space than a 100A meter base for a 480V service. In this instance, the wiring in the weatherhead does not have to be sized for 200A. It may be sized smaller to match the main breaker size.
7. 240/480V Delta with Three Transformers

This installation is very similar to a 120/240V Delta with Three Transformers. See Section 2 for a more complete description.
8. 480V Delta Three Phase with Three Transformers

This installation is very similar to a 120/240V Delta with Three Transformers. See also Section 6 for additional details.
9. 277/480V Y Three Phase

This installation is very similar to 120/208V Y Three Phase installation. See Section 3 for a more complete description.
10. 277/480V Y Three Phase with Pad-Mounted Transformer

This installation is very similar to 120/208V Y Three Phase installation. See Section 4 for a more complete description. It typically used for larger three phase applications. Common transformer sizes for this voltage are 300kVA, 500kVA, 750kVA, 1000kVA, 1500kVA, 2000kVA, 2500kVA, and 3000kVA. For 500kVA transformer and larger, an engineering study should be prepared for coordination and capacity requirements. Lower limits are required for specific feeders and locations.

In addition to CT’s, the metering for this voltage will require potential transformers (PT’s). A PT reduces the voltage from 480V to 120V. It may also be called a voltage transformer (VT).
11. 2400V Delta Three Phase

This is a specific voltage used for very large applications. We have only one member with this voltage configuration. A detailed engineering study will be required for this request.
12. 2400/4160V Y Three Phase

This is also a specific voltage used for very large applications. This is a 4 wire service. The phase-to-ground voltage is 2400V. The phase-to-phase voltage is 4160V. This is typically a pad-mounted or substation type transformer. The transformer has a delta connection on the primary side and a wye connection on the secondary side.

Metering is provided either in a separate metering cabinet or with a primary meter set.
TRI-COUNTY ELECTRIC

ELECTRIC LOAD REQUIREMENTS FORM

Project/Customer Name: ___________________________________________________

**Requested Voltage** (Select only one): Single Phase 120/240___, 3 Phase 120/208Y ___
3 Phase 120/240 Delta ___, 3 Phase 277/480Y___, 3 Phase 480 Delta ___
Other __________________________________________________________________

Indicate Only One: New Load _____ Adding Load to an Existing Service_____.

**ELECTRICAL LOAD REQUIREMENTS:**

**HVAC LOAD INFORMATION:**

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**TOTAL CONNECTED LOADS**

Total Connected Amps _________
Total Connected KW _________

Signature-required                            Title                                            Date-required
___________________________________________   _____________________________________________

Phone                                      Address