ECET 4520

Industrial Distribution Systems, Illumination, and the NEC

Three-Phase & Single-Phase Distribution System Characteristics

Electric Distribution Systems

This presentation provides an overview of several common electric distribution system configurations, with a primary focus on the different voltages provided by those systems and the types of loads that they may serve.

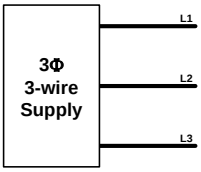
Note that, although an important part of a distribution system, grounding conductors are <u>not</u> included in this discussion.

Common Distribution Systems

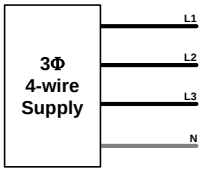
There are many different configurations that are used for electric distribution systems, the choice of which depends on the specific needs of the loads being served.

Some of the more common system configurations are:

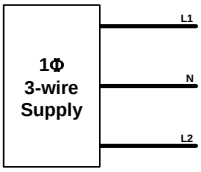
3Φ 3-Wire



3Φ 4-Wire



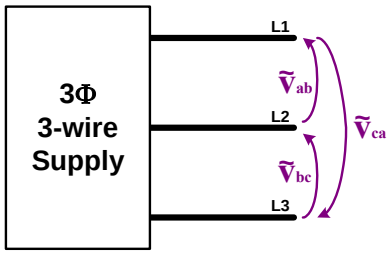
1Φ 3-Wire



3Φ 3-Wire Systems

A 3Φ, 3-wire system utilizes three energized conductors to distribute electric energy.

For this system, a set of "line voltages" are defined as the voltages that exist between the different pairs of energized conductors.



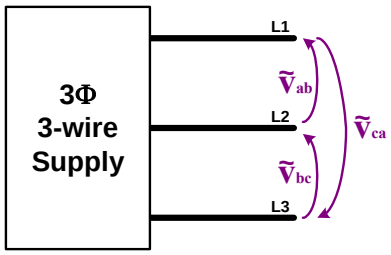
3Φ 3-Wire Systems

In a balanced 3Φ system, the line voltages will have equal magnitudes but will differ in phase by 120°.

$$\tilde{V}_{ab} = V_{Line} \angle \phi_L °$$

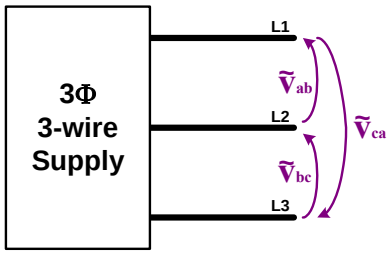
$$\tilde{V}_{bc} = V_{Line} \angle \phi_L ° - 120°$$

$$\tilde{V}_{ca} = V_{Line} \angle \phi_L ° - 240°$$



3Φ 3-Wire Systems

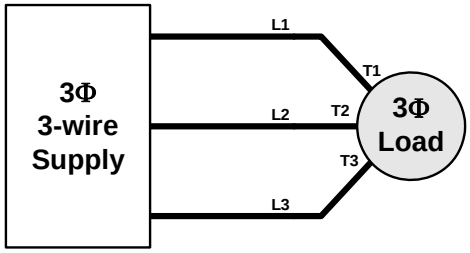
Note that although 3Φ, 3-wire systems are not as common as 4-wire systems in industrial applications, they are worth mentioning because the serving utilities typically distribute power to their customers using this type of system.



3Φ 3-Wire Systems

The 3-wire system can be used to supply both 3Φ and 1Φ loads.

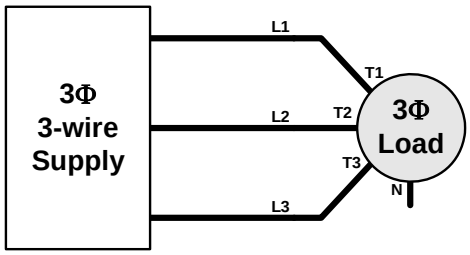
When supplying a 3Φ, Δ-connected (3-terminal) load, all three of the energized conductors are connected to the load, providing a balanced set of line-voltages across the load's terminals.



3Φ 3-Wire Systems

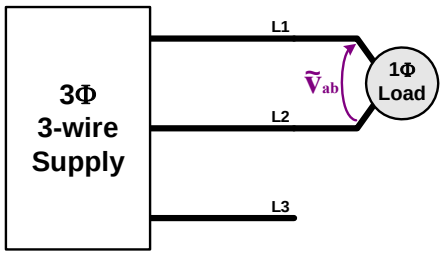
The 3-wire system can be used to supply both 3Φ and 1Φ loads.

Note that a 3-wire system can be used to supply a 3Φ, Y-connected (4-terminal) load but that there is no neutral wire available to connect to the neutral terminal of the load.



3Φ 3-Wire Systems

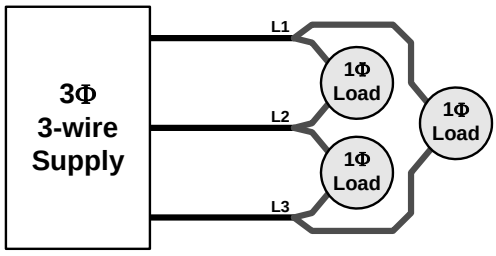
When supplying a 1Φ load, a pair of the energized conductors are connected to the load, providing a single line-voltage across the load's terminals.



3Φ 3-Wire Systems

When supplying a 1Φ load, a pair of the energized conductors are connected to the load, providing a single line-voltage across the load's terminals.

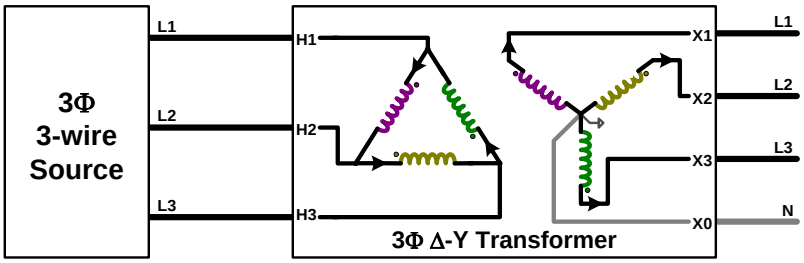
Multiple 1Φ loads are often connected across different pairs of conductors in order to balance out the overall load on the supply.



3Φ 3-Wire to 4-Wire Conversion

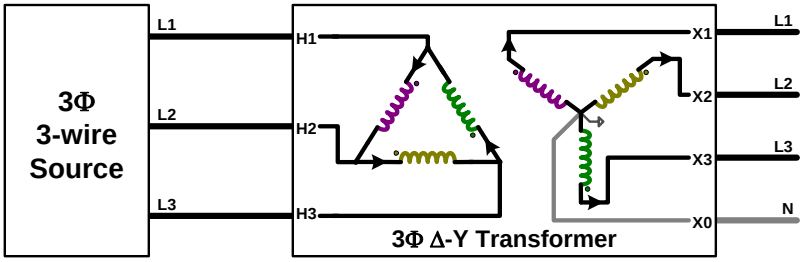
A 3-wire system may be transformed into a 4-wire (wye) system by means of a 3Φ, Δ-Y transformer.

The common node of the wye-connected secondary windings is typically grounded in order to provide a 0-volt reference for the 4-wire system.



3Φ 3-Wire to 4-Wire Conversion

Since 4-wire (wye) systems are typically utilized for large industrial applications, this conversion often occurs at the point of connection to the local utility's 3-wire distribution system.

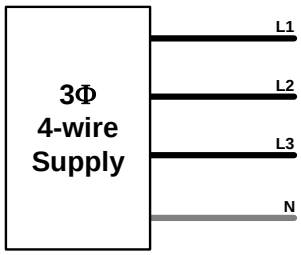


3Φ 4-Wire (Wye) Systems

A 3Φ, 4-wire (wye) system utilizes three energized conductors along with a neutral conductor to distribute electric energy.

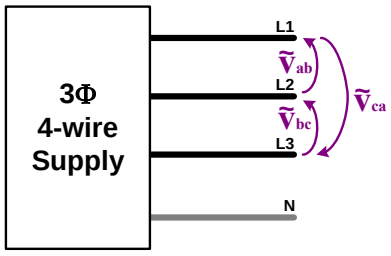
Note – This presentation only covers 4-wire wye systems.

4-wire delta systems are configured differently, so care should be taken to determine the type of 4-wire system that is present before connecting any loads.



3Φ 4-Wire (Wye) Systems

As with the 3-wire system, a set of "line-voltages" are defined as the voltages that exist between the different pairs of energized conductors of the 4-wire system.



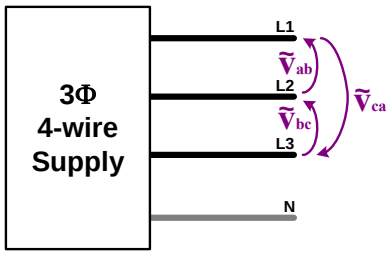
3Φ 4-Wire (Wye) Systems

In a balanced 3Φ system, the line-voltages will have equal magnitudes but will differ in phase by 120°.

$$\tilde{V}_{ab} = V_{Line} \angle \phi_L^{\circ}$$

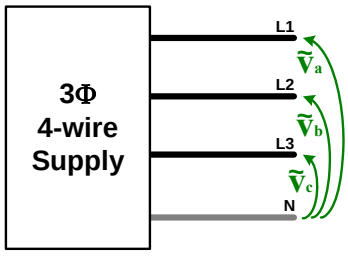
$$\tilde{V}_{bc} = V_{Line} \angle \phi_L^{\circ} - 120^{\circ}$$

$$\tilde{V}_{ca} = V_{Line} \angle \phi_L^{\circ} + 120^{\circ}$$



3Φ 4-Wire (Wye) Systems

Additionally, a set of "phase-voltages" can be defined as the voltages that exist between the neutral wire and each energized conductor of the 4-wire system.



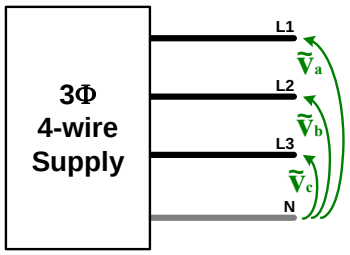
3Φ 4-Wire (Wye) Systems

The phase-voltages will also maintain a balanced relationship:

$$\tilde{V}_a = V_{Phase} \angle \phi_P^\circ$$

$$\tilde{V}_b = V_{Phase} \angle \phi_P^\circ - 120^\circ$$

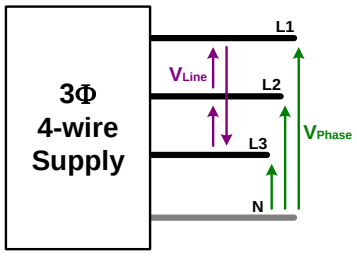
$$\tilde{V}_c = V_{Phase} \angle \phi_P^\circ + 120^\circ$$



3Φ 4-Wire (Wye) Systems

The line-voltage magnitudes will be $\sqrt{3}$ times greater than the phase-voltage magnitudes:

$$V_{Line} = \sqrt{3} \cdot V_{Phase}$$

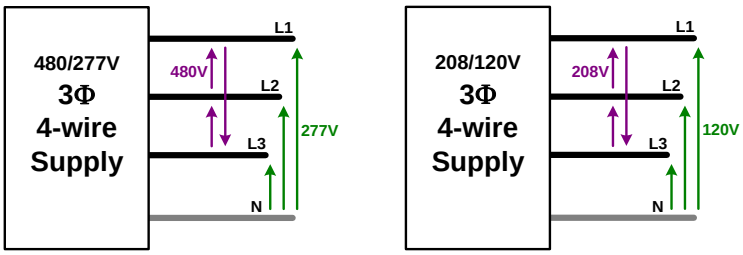


3Φ 4-Wire (Wye) Systems

The line-voltage magnitudes will be $\sqrt{3}$ times greater than the phase-voltage magnitudes:

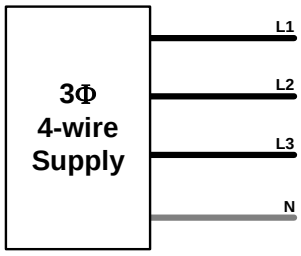
$$V_{Line} = \sqrt{3} \cdot V_{Phase}$$

Standard line/phase-voltage magnitudes in the 0-600V range include: 480/277V & 208/120V



3Φ 4-Wire (Wye) Systems

The 4-wire system can also be used to supply both 3Φ and 1Φ loads, but it allows for more connection possibilities than a 3-wire system.

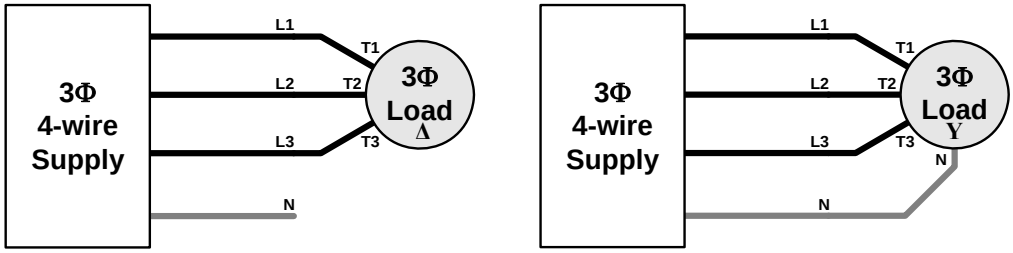


3Φ 4-Wire (Wye) Systems

A 3Φ, Δ-connected (3-terminal) load can be connected to all three of the energized conductors.

A 3Φ, Y-connected load can be connected to all three of the energized conductors along with the neutral conductor.

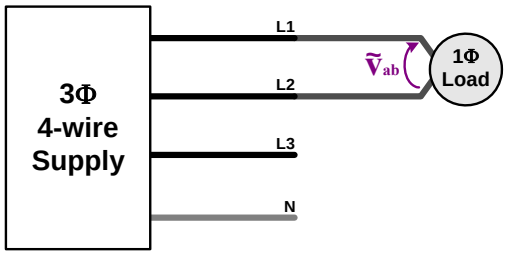
Note – The neutral conductor is not required for balanced, Y-connected loads.



3Φ 4-Wire (Wye) Systems

A 1Φ load can either be connected:

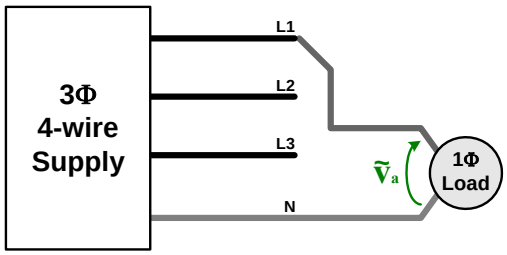
- Across a pair of energized conductors, providing a "line voltage" across the load terminals, or



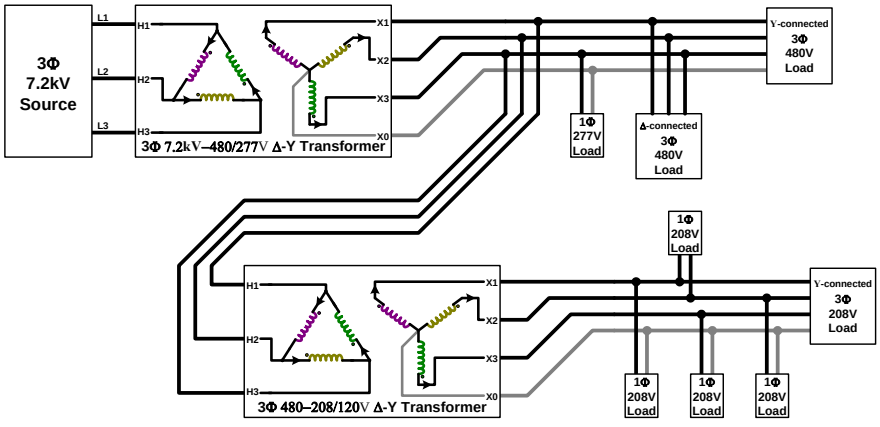
3Φ 4-Wire (Wye) Systems

A 1Φ load can either be connected:

- Across a pair of energized conductors, providing a "line voltage" across the load terminals, or
- **Between an energized conductor and the neutral conductor, providing a "phase voltage" across the load terminals.**



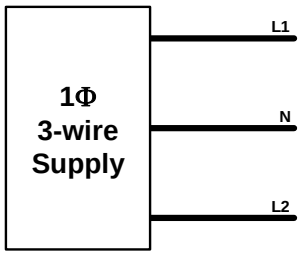
3Φ Distribution System Example



1Φ 3-Wire Systems

A 1Φ, 3-wire distribution system is typically used for residential applications.

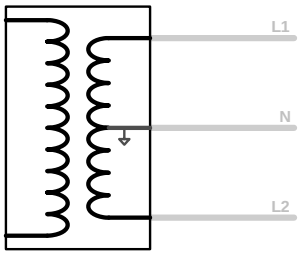
This type of system utilizes two energized conductors along with a neutral conductor to distribute electric energy to its loads.



1Φ 3-Wire Systems

The 1Φ, 3-wire system is supplied by a single-phase transformer, the secondary-winding of which is center-tapped and grounded.

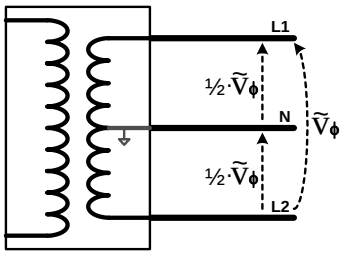
The energized conductors are connected to the end-points of the secondary-winding, while the neutral conductor is connected to the center-tap.



1Φ 3-Wire Systems

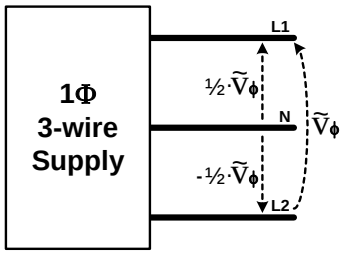
In this configuration, the entire secondary voltage exists between the two energized conductors while one-half of that voltage exists between the neutral and either energized conductor.

For this reason, a 1Φ, 3-wire system is sometimes referred to as a "split-phase" system.



1Φ 3-Wire Systems

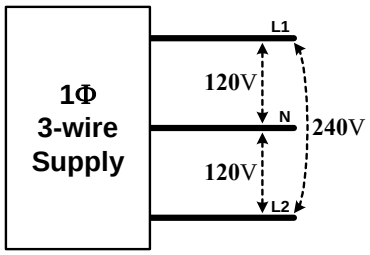
Note that the voltages across each half of the secondary winding are typically defined as the voltage-rises from the neutral conductor to the energized conductors. If defined in that manner, then the two line-to-neutral voltages would be the negative of each other or out-of-phase by 180°.



1Φ 3-Wire Systems

The 1Φ, 3-wire system operates with a standard line-to-line voltage magnitude of 240V and a line-to-neutral voltage magnitude of 120V.

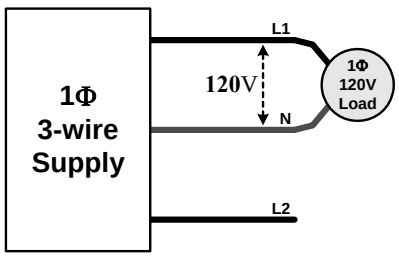
Thus, the system can be used to supply 1Φ loads requiring either of those voltage potentials.



1Φ 3-Wire Systems

Most residential loads (televisions, computers, lights, microwaves, ceiling fans, etc.) consume relatively low power during operation.

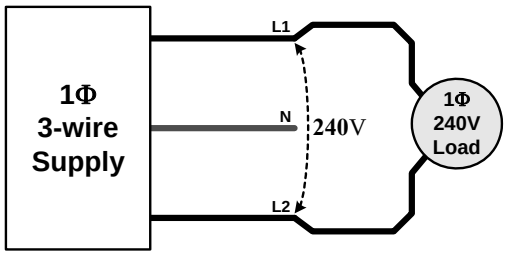
These low-power loads are designed to be supplied at 120V, and thus are connected between the neutral conductor and either of the energized conductors.



1Φ 3-Wire Systems

A few residential loads (clothes dryer, electric oven, AC compressor, etc.) consume larger amounts of power.

These loads are designed to be supplied at 240V in order to minimize the supply current, and thus are connected between the energized conductors.



1Φ 3-Wire Systems

When serving multiple 120V loads, the loads should be distributed evenly to balance the overall current-flow through the secondary-winding of the transformer.