



Power Measurements

Technology Consulting

William H. Hardy, PhD

6386 Avington Place

Gainesville, VA 20155

Cell: (865) 279-1090

www.powermeasurements.com

Bill.Hardy@PowerMeasurements

Metering US Services

- The US has the widest variety of power services in the world
- The rest of the world basically has only two services:
 - Single phase 2-Wire w/wo ground
 - 4-Wire Wye Three Phase

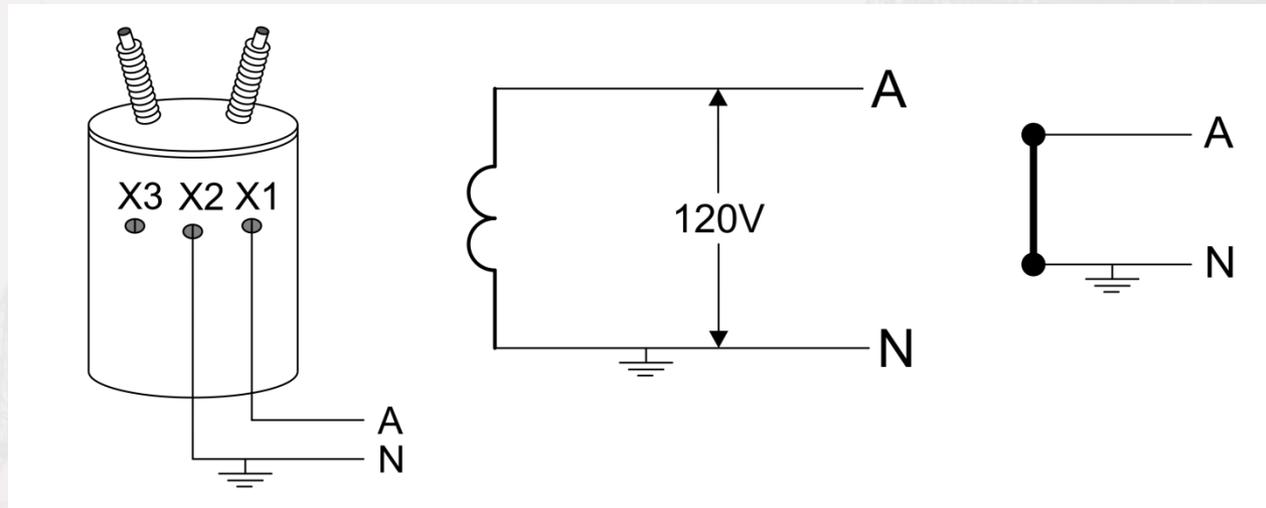
US Services

Description	L-N VAC	L-L VAC	Area	Designation
1-Phase, 2-Wire 120V with Neutral	120	-	US	1P-2W (120V)
1-Phase, 2-Wire 208V †	-	208	US	1P-2W (208V)
1-Phase, 2-Wire 240V †	-	240	US	1P-2W (240V)
1-Phase 3-Wire 120/240V (Residential)	120	240	US	1P-3W (240V)
1-Phase 3-Wire 120/208V (Network)	120	208	US	1P-3N (208V)
3-Phase, 3-Wire 208V Delta †	-	208	US	3P-3D (208V)
3-Phase, 3-Wire 480V Delta †	-	480	US	3P-3D (480V)
3-Phase, 3-Wire 600V Delta †	-	600	US, Ca	3P-3D (600V)
3-Phase, 4-Wire Wye 120/208V	120	208	US	3P-4Y (208V)
3-Phase, 4-Wire Wye 277/480V	277	480	US	3P-4Y (480V)
3-Phase, 4-Wire Wye 347/600V	347	600	US, Ca	3P-4Y (600V)
3-Phase, 4-Wire Delta 120/208/240V	120 208	240	US	3P-4D (240V)
3-Phase, 4-Wire Delta 240/415/480V	240 415	480	US	3P-4D (480V)

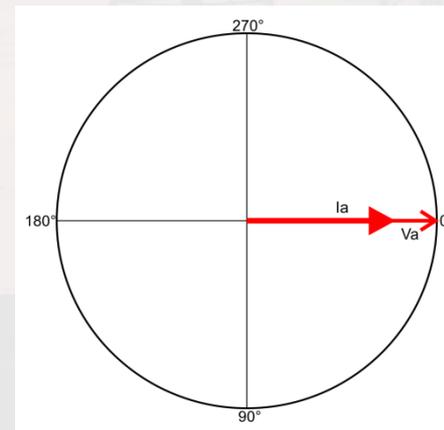
† These services have no neutral conductor.

Single Phase Services

1-Phase, 2-Wire 120V with neutral

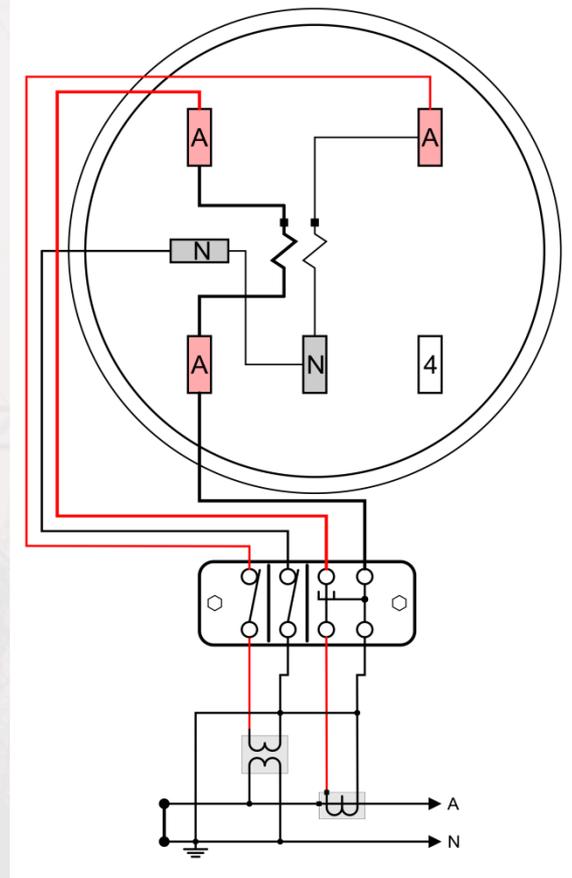


A service that was common in residential applications several decades ago. Because it lacks a safety ground its use has been generally discontinued.

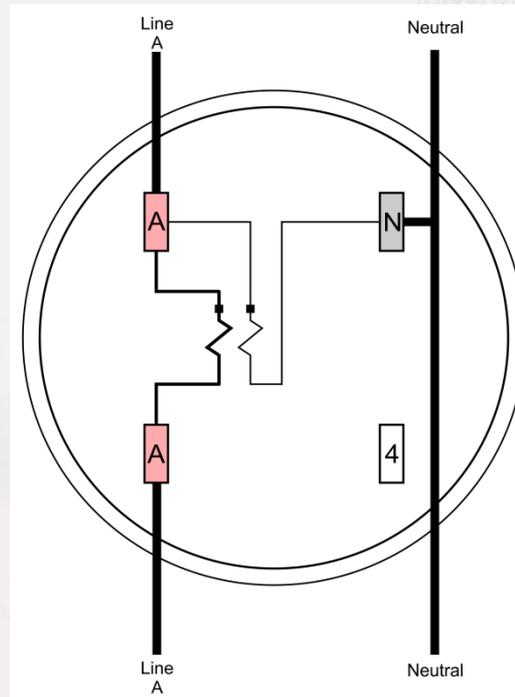


Single Phase Services

1-Phase, 2-Wire 120V with neutral



3S Transformer Rated Service



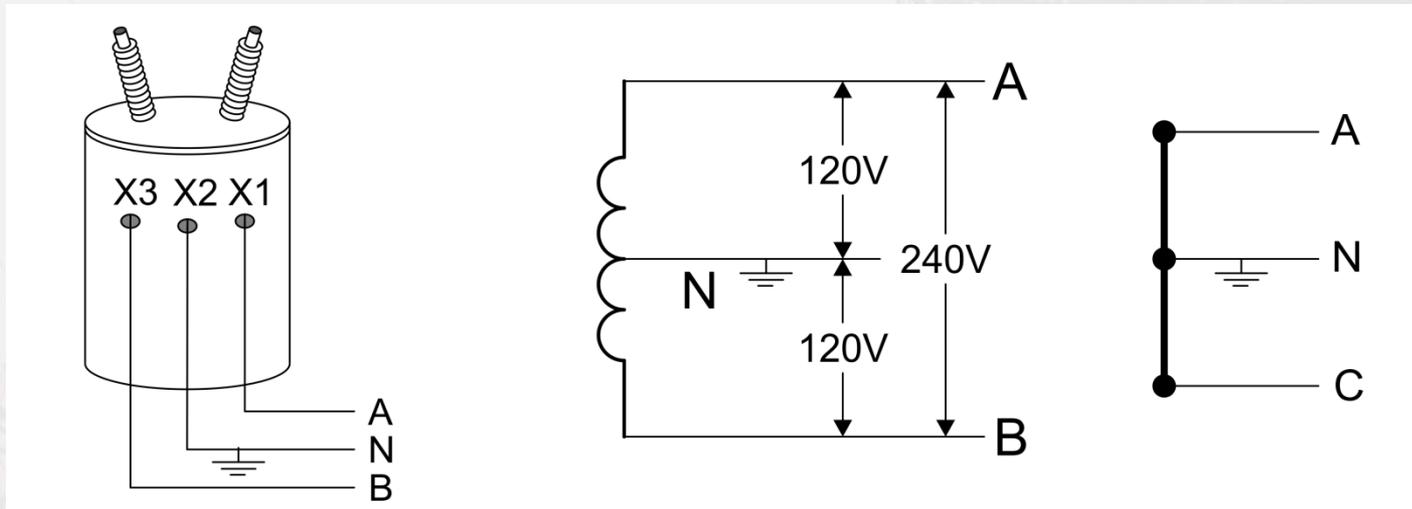
1S Self Contained Service

This is a Blondel compliant service. It is often used for small applications like traffic lights. The power equation is:

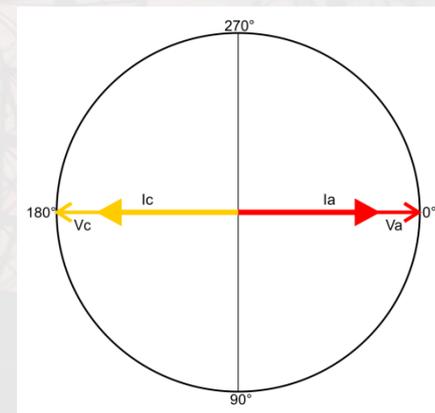
$$P = \vec{V}_a \bullet \vec{I}_a$$

Single Phase Services

1-Phase, 3-Wire 120/240V

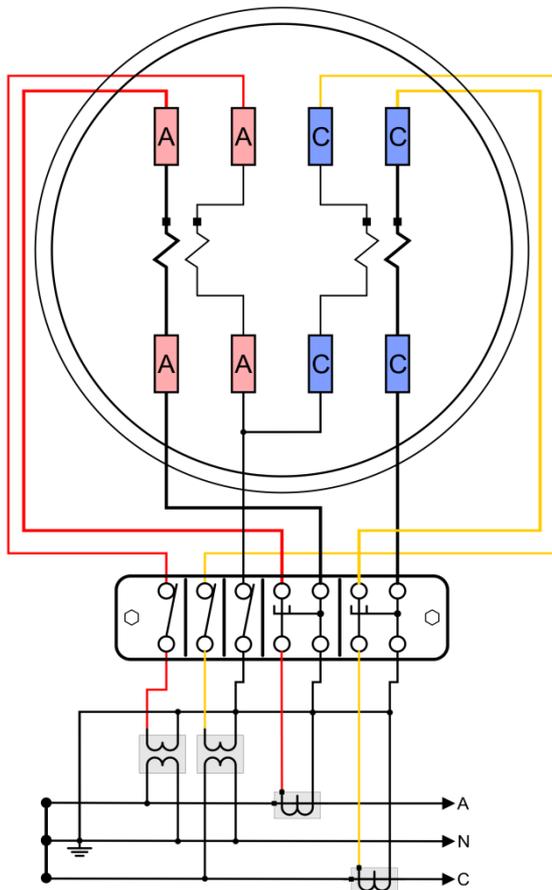


The most common residential and light commercial service. Both Blondel and non-Blondel metering applications are common.

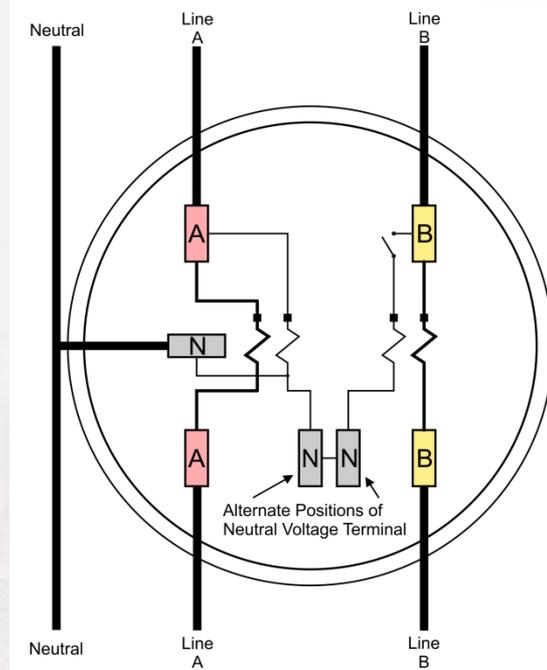


Single Phase Services

1-Phase, 3-Wire 120/240V



5S Transformer Rated Service



12S Self Contained Service

These are Blondel metering applications. The 12S is most often used for small commercial customers. The 5S while designed for 3-wire delta service, can be used here if a transformer rated meter is needed. The power equation is:

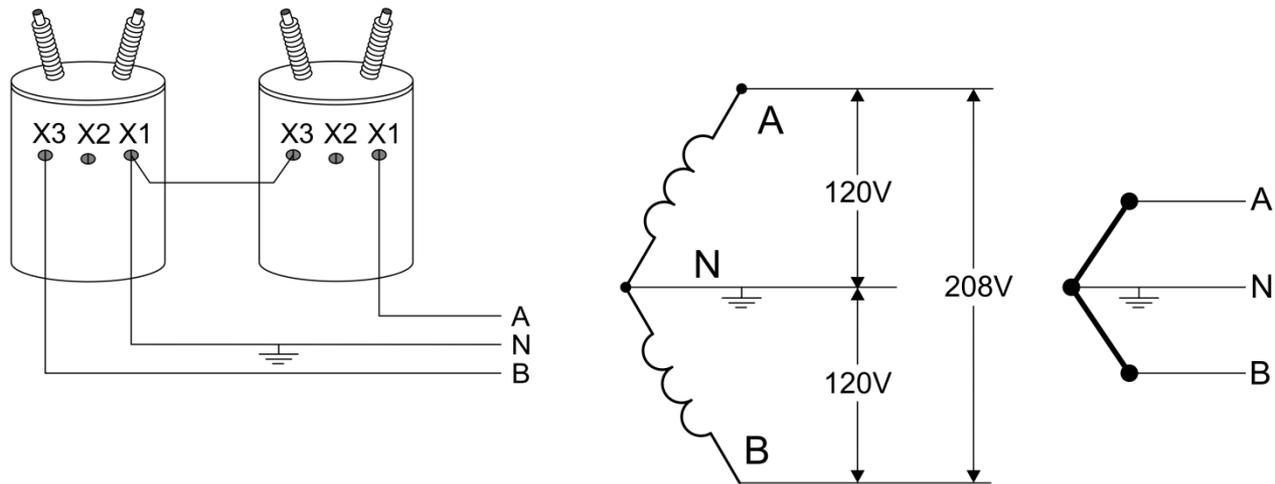
$$P = \vec{V}_a \bullet \vec{I}_a + \vec{V}_b \bullet \vec{I}_b$$

Other meter forms which can be used:

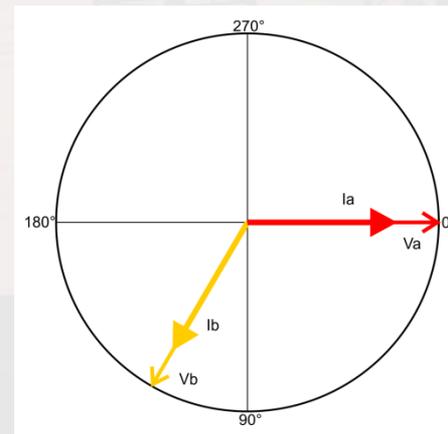
Blondel: 13S, 25S, 26S, 32S, 45S, 56S

Single Phase Services

1-Phase, 3-Wire "Network" 120/208V

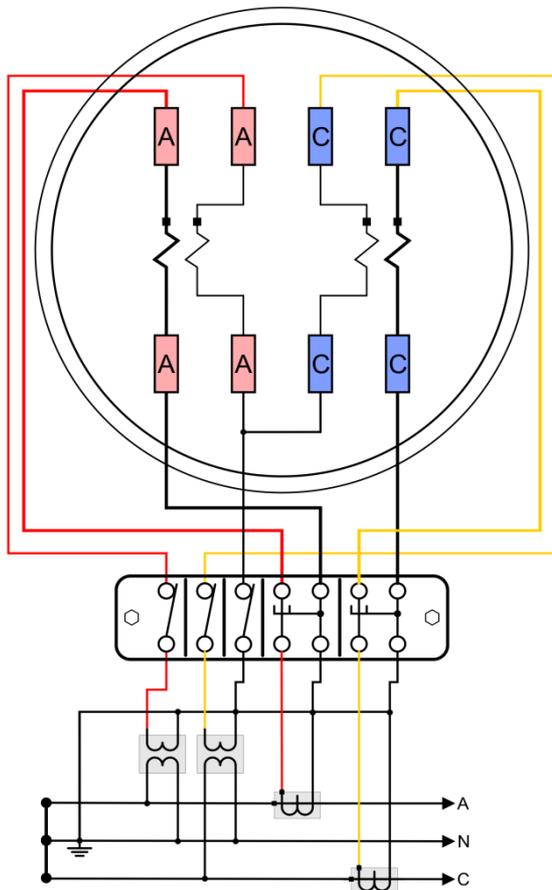


Common in small commercial applications where the transformer bank is a 4-Wire Wye. Usually metered in a Blondel compliant manner with a 12S or 5S meter.

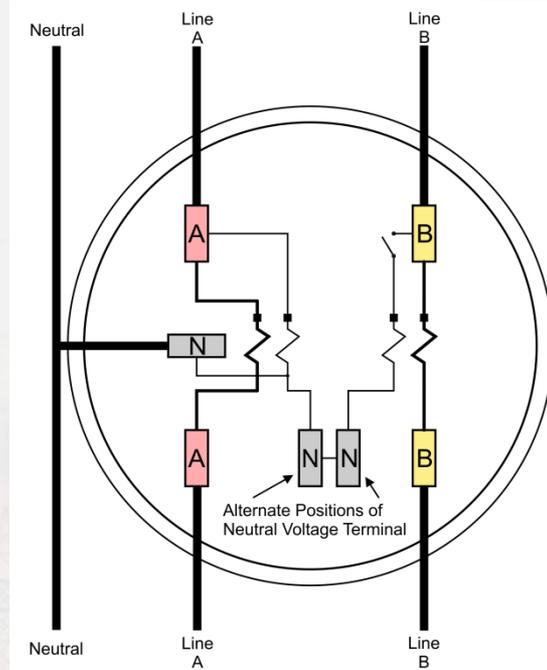


3-Wire “Network” Services

1-Phase, 3-Wire 120/208V



5S Transformer Rated Service



12S Self Contained Service

These are Blondel metering applications. The 12S is most often used for small commercial customers. The 5S while designed for 3-wire delta service, can be used here if a transformer rated meter is needed. The power equation is:

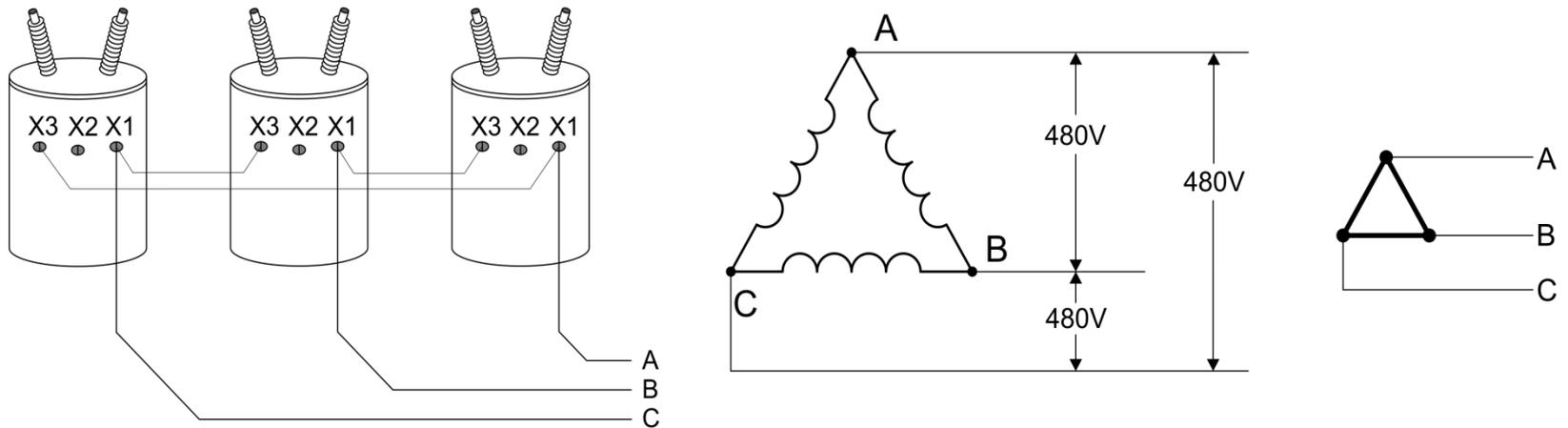
$$P = \vec{V}_a \bullet \vec{I}_a + \vec{V}_b \bullet \vec{I}_b$$

Other meter forms which can be used:

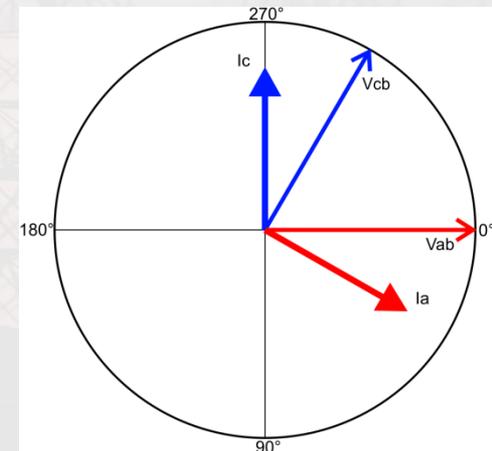
Blondel: 13S, 25S, 26S, 32S, 45S, 56S

3-Wire Delta Service

3-Phase, 3-Wire Delta 480V

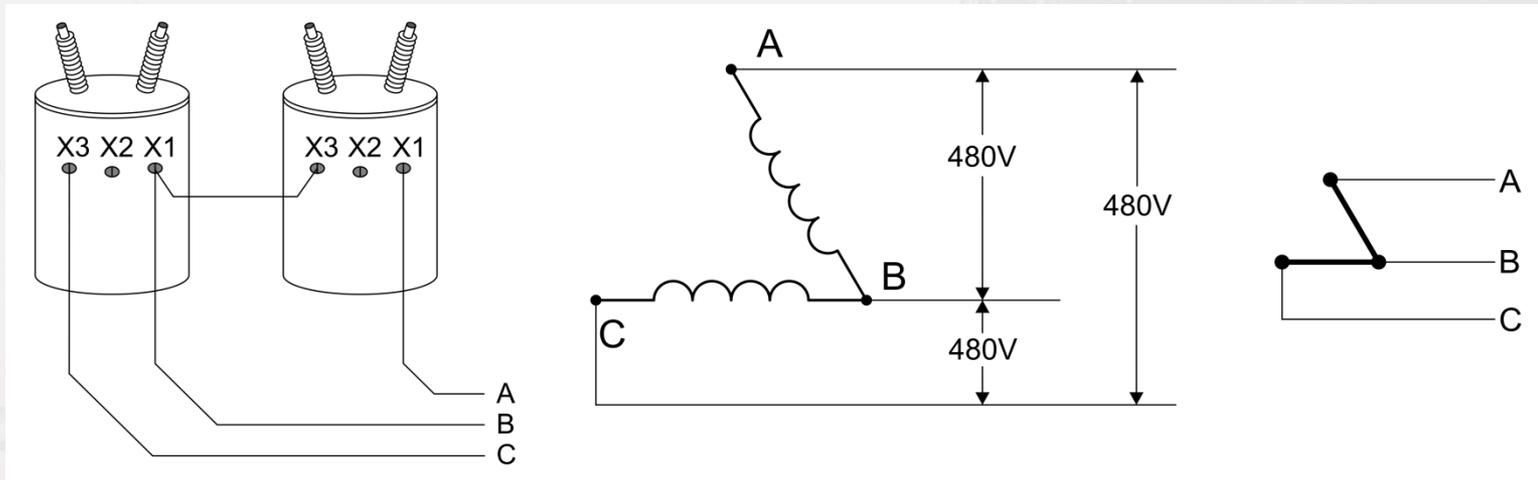


This service has NO NEUTRAL conductor. It is common where only heavy motor loads are present. Other phase to phase voltages common for this service are: 120V and 240V. All metering applications for this service are Blondel Compliant. Some utilities ground one phase (generally B).

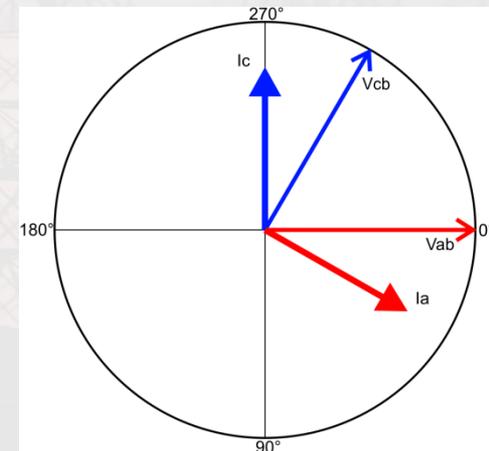


3-Wire Delta Service

3-Phase, 3-Wire "OPEN" Delta 480V



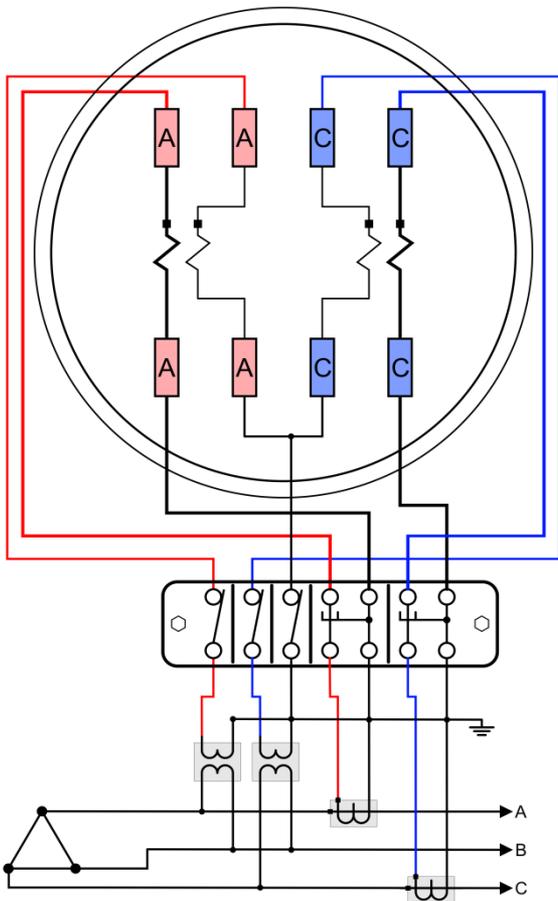
One of the unique properties of the delta configuration is that you can remove one transformer without affecting the basic properties of the service. However, the maximum current is reduced to 57% and the harmonic trapping property of the configuration is lost.



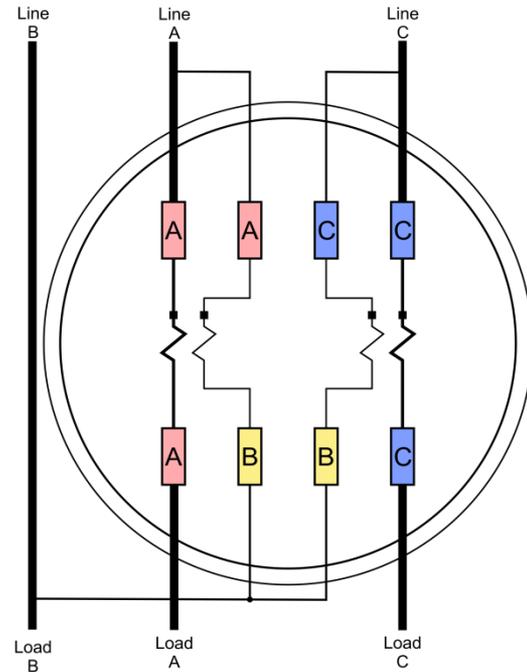
Power Measurements

3-Wire Delta Service

3-Phase, 3-Wire Delta 480V



5S Transformer Rated Service



13S Self Contained Service

These are Blondel metering applications. Most 3-wire delta services supply heavy loads so are transformer rated installations. The 5S and 45S are the most common meters. The power equation is:

$$P = \vec{V}_{ab} \bullet \vec{I}_a + \vec{V}_{cb} \bullet \vec{I}_c$$

Other meter forms which can be used:

Blondel: 25S, 26S, 32S, 45S, 46S, 56S, 66S

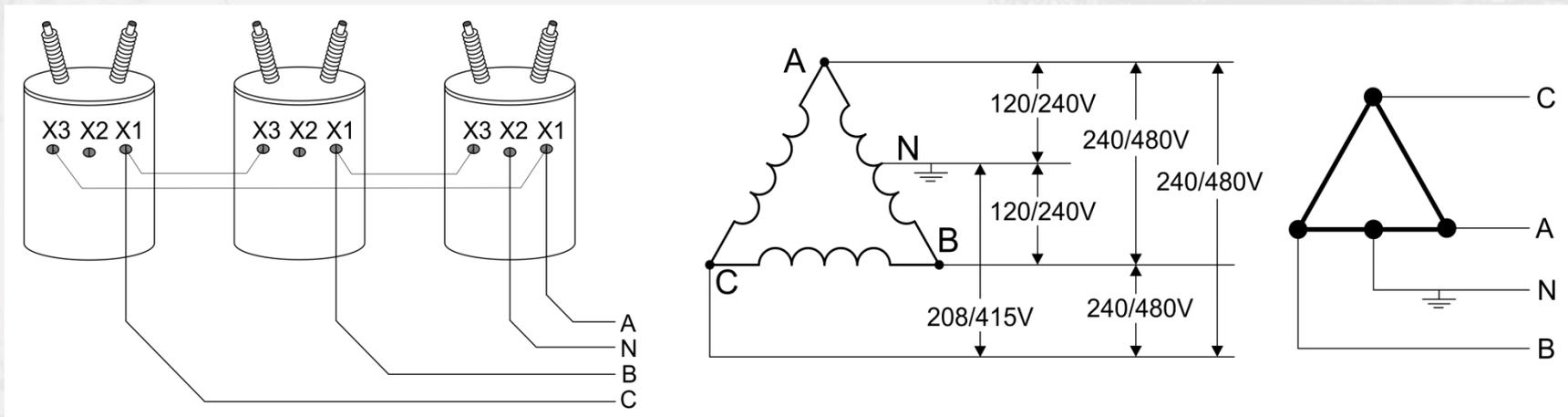
4-Wire Delta Service

3-Phase, 4-Wire Delta 480V

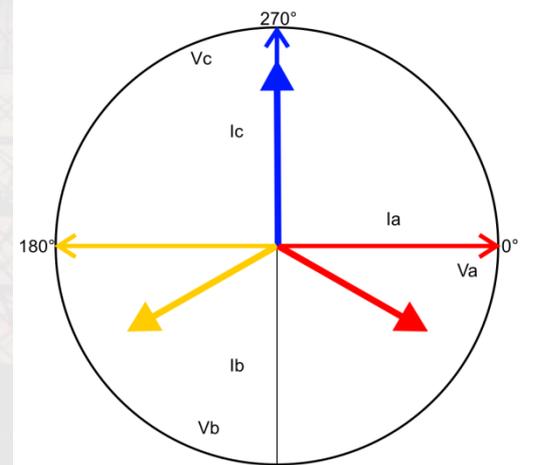
- Many different metering approaches both Blondel and non-Blondel
 - Historically there have been many “cost saving” non-Blondel approaches.
 - These non-Blondel approaches can have large ($>2\%$) inherent errors under complex loads.

4-Wire Delta Service

3-Phase, 4-Wire Delta 480V

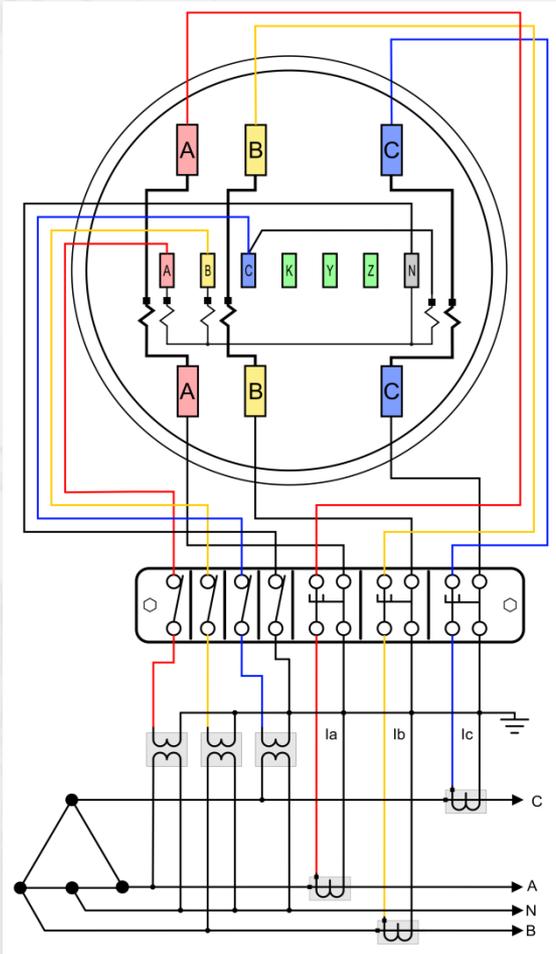


This service is created by adding a center tap to one side of the delta and grounding it. It is a very versatile service in that it provides many different voltages: 120V single phase, 208V single phase, and 480V delta.

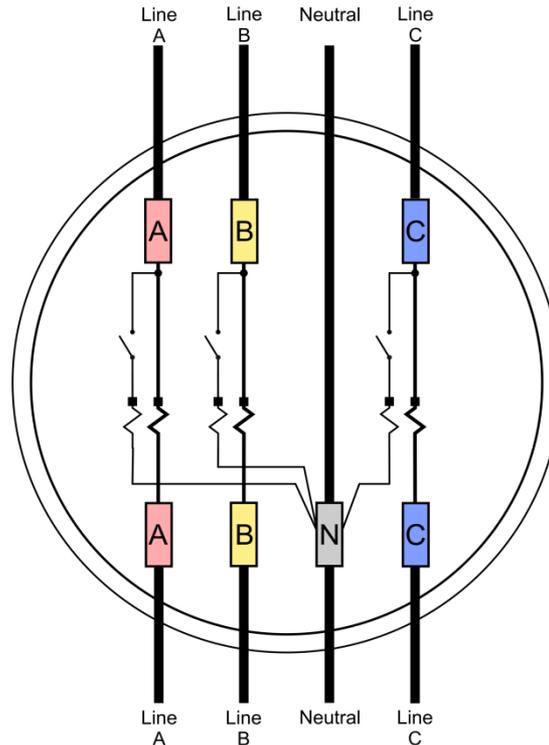


4-Wire Delta Service

3-Phase, 4-Wire Delta 480V



9S Transformer Rated Service



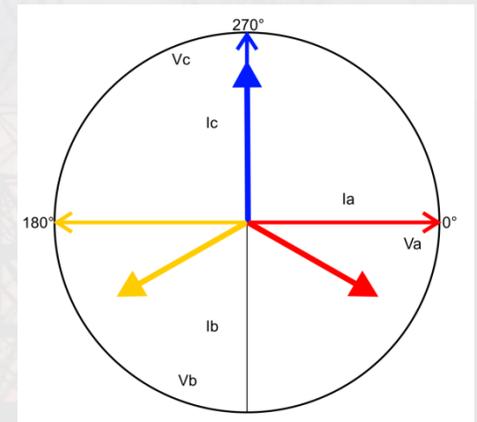
16S Self Contained Service

Other meter forms which can be used:

Blondel: 10S, 11S, 24S

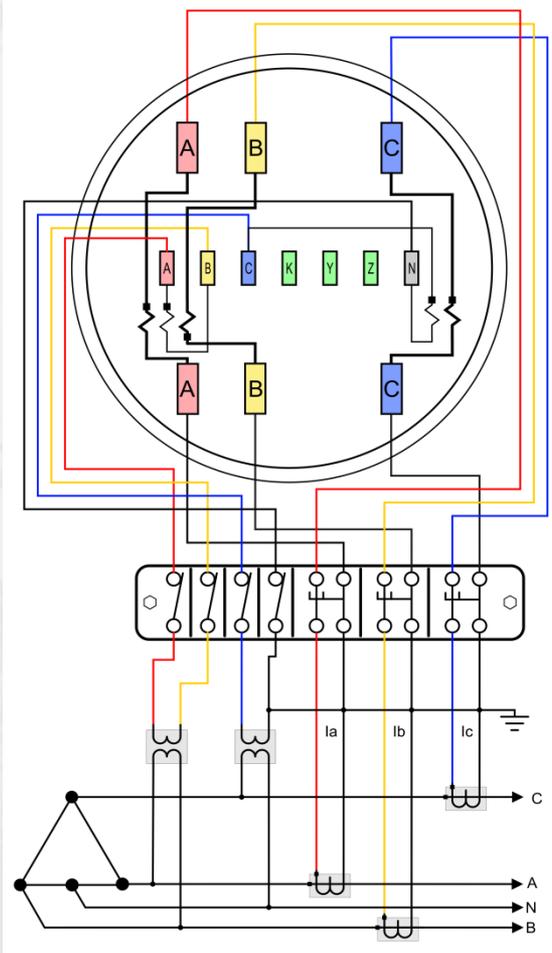
These are Blondel metering applications. The power equation is:

$$P = \vec{V}_a \bullet \vec{I}_a + \vec{V}_b \bullet \vec{I}_b + \vec{V}_c \bullet \vec{I}_c$$

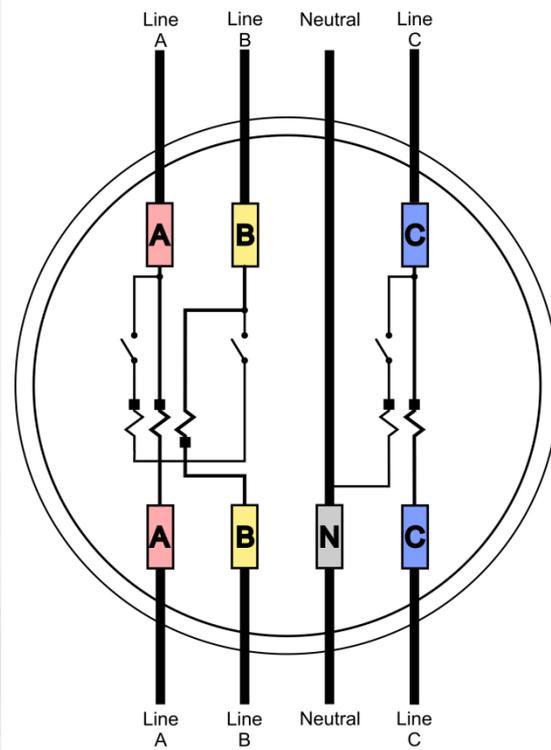


4-Wire Delta Service

3-Phase, 4-Wire Delta 480V



8S Transformer Rated Service

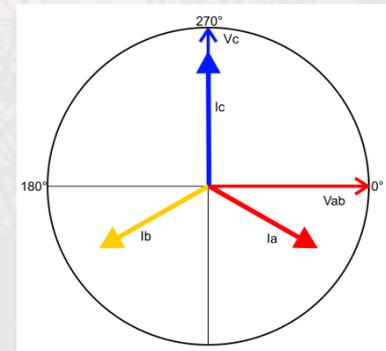


15S Self Contained Service

Other meter forms which
can be used:
non-Blondel: 24S

These are non-Blondel metering applications. Phases A & B are metered like a 3-Wire SP service. Phase C is metered as a 2-Wire SP service. The power equation is:

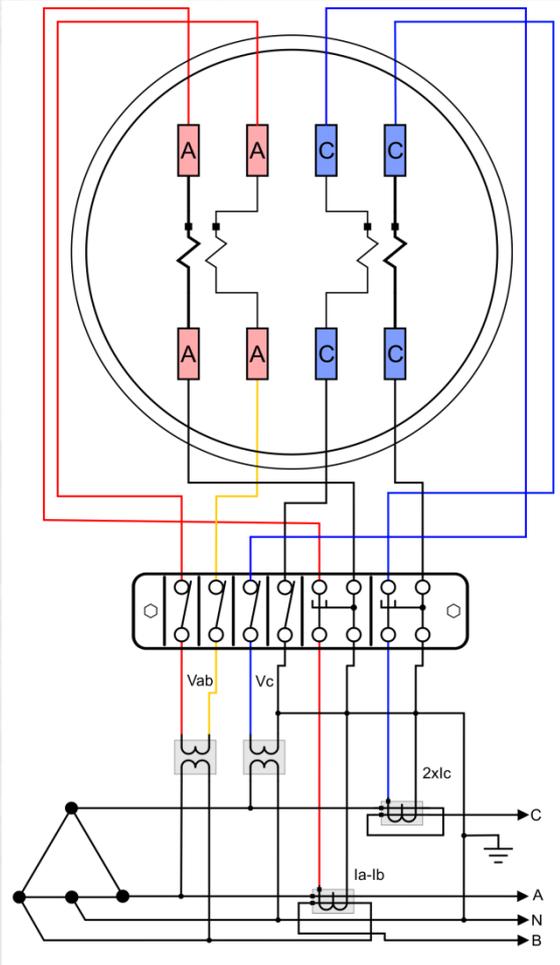
$$P = 0.5 * \vec{V}_{ab} \bullet (\vec{I}_a - \vec{I}_b) + \vec{V}_c \bullet \vec{I}_c$$



Power Measurements

4-Wire Delta Service

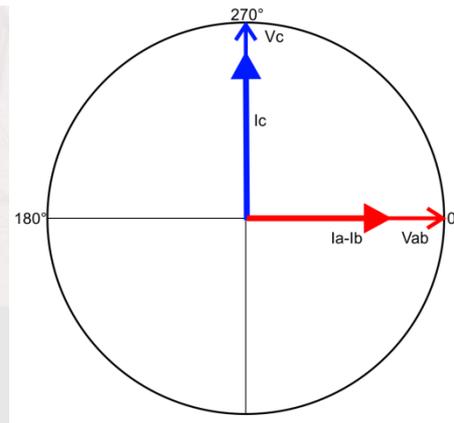
3-Phase, 4-Wire Delta 480V



5S Transformer Rated Service

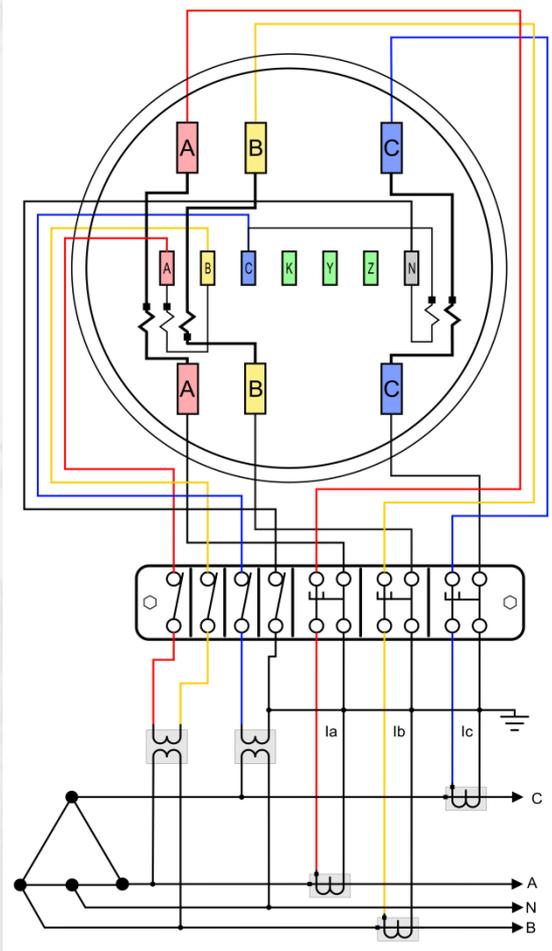
While the 5S is listed as a Blondel meter, this is not a Blondel compliant application. It uses external CTs with multiple wires to create a metering equation similar to the 8S. The meter measures 2X the actual power in this configuration so the transformer **multiplier must be reduced by half**. The power equation is:

$$P = \vec{V}_{ab} \bullet (\vec{I}_a - \vec{I}_b) + 2 * \vec{V}_c \bullet \vec{I}_c$$

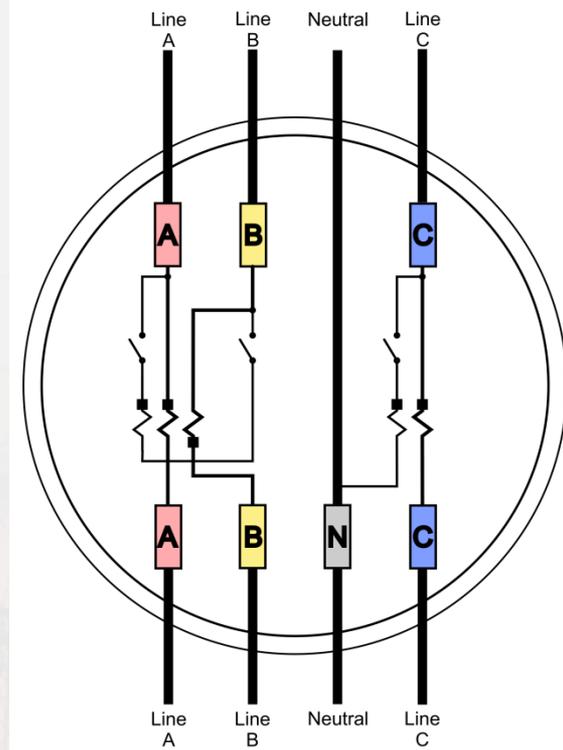


4-Wire Delta Service

3-Phase, 4-Wire Delta 480V



8S Transformer Rated Service



15S Self Contained Service

These are non-Blondel metering applications. .
The power equation is:

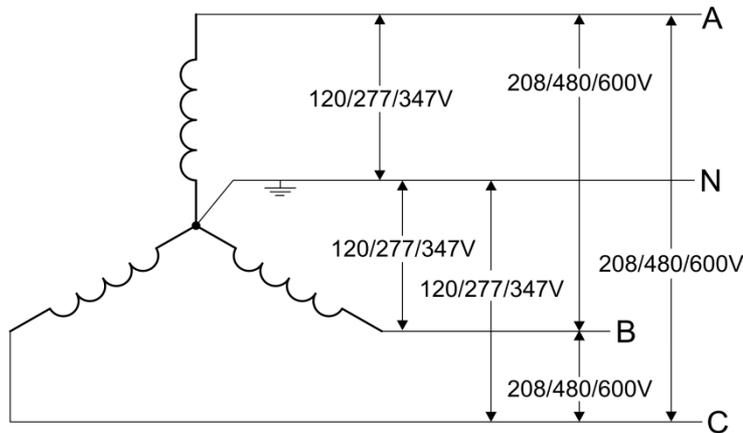
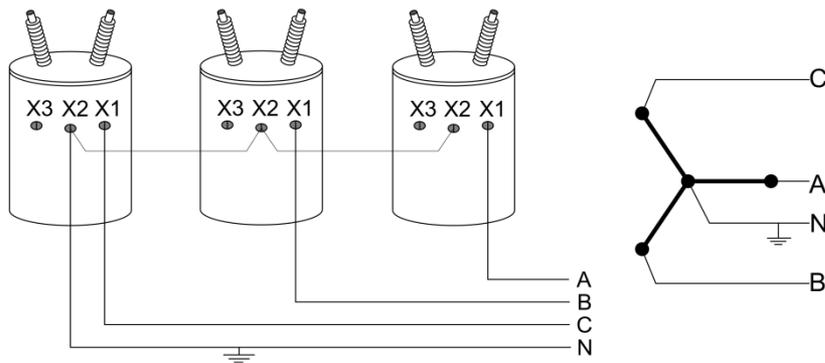
$$P = 0.5 * \vec{V}_{ab} \bullet (\vec{I}_a - \vec{I}_b) + \vec{V}_c \bullet \vec{I}_c$$

Other meter forms which can be used:

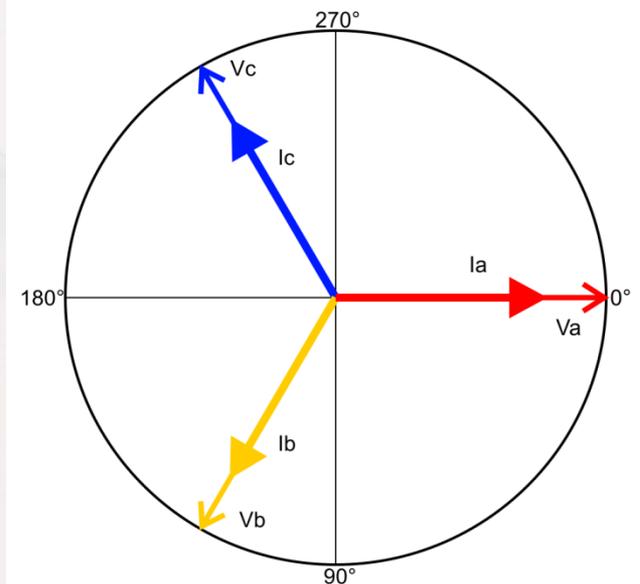
Blondel: 25S, 26S, 32S, 45S, 46S, 56S, 66S

4-Wire Wye Service

3-Phase, 4-Wire Wye 208V

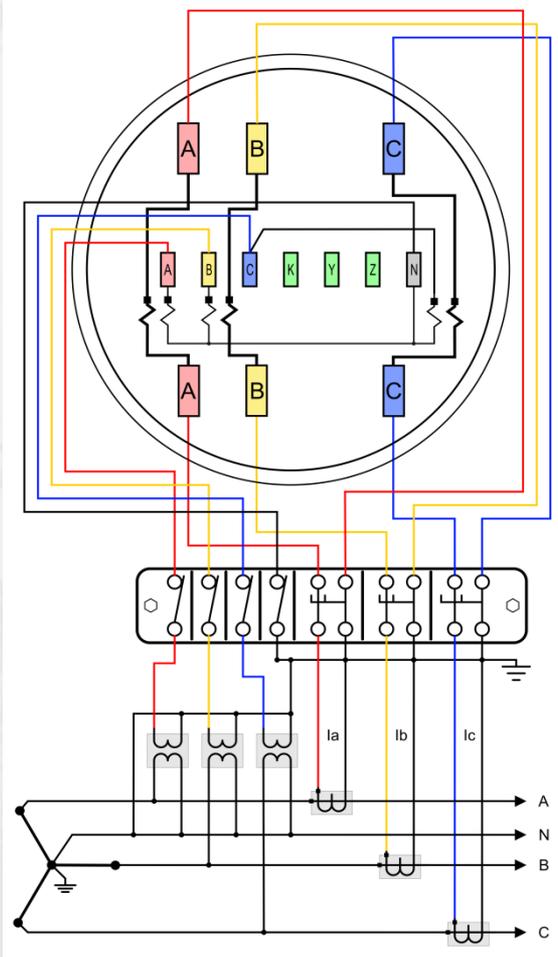


The most common industrial service.

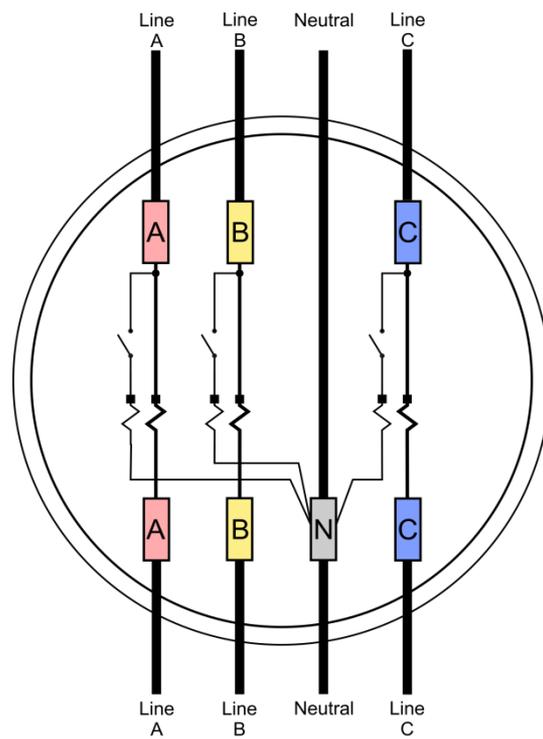


4-Wire Wye Service

3-Phase, 4-Wire Wye 208/480/600V



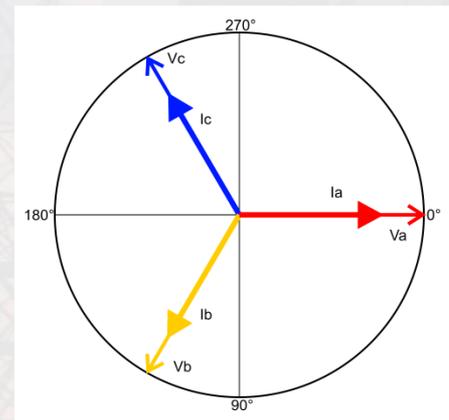
9S Transformer Rated Service



16S Self Contained Service

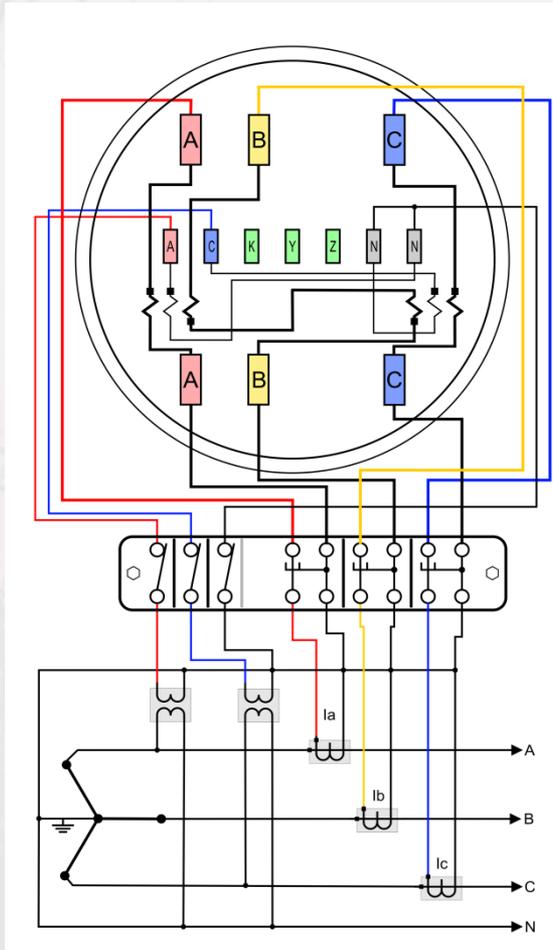
These are Blondel metering applications with 3 voltages and 3 currents. The power equation is:

$$P = \vec{V}_a \bullet \vec{I}_a + \vec{V}_b \bullet \vec{I}_b + \vec{V}_c \bullet \vec{I}_c$$

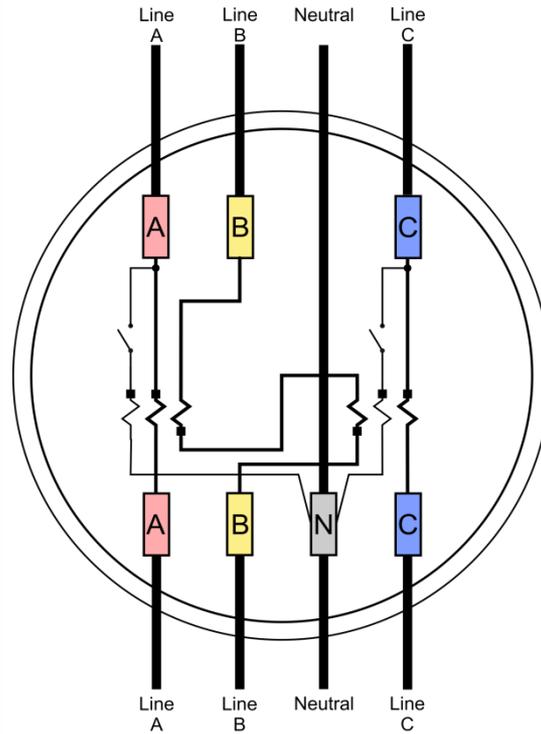


4-Wire Wye Service

3-Phase, 4-Wire Wye 208/480/600V



6S Transformer Rated Service

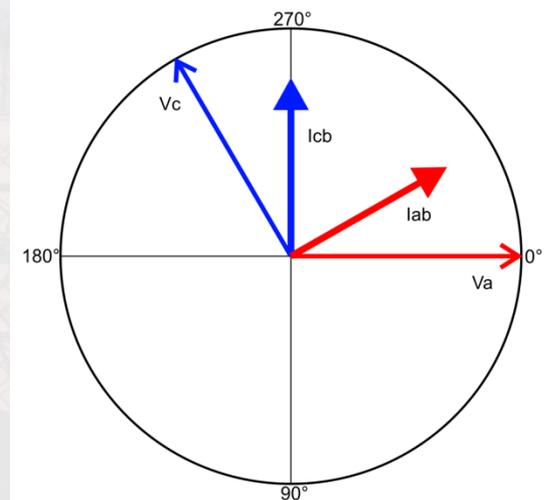


14S Self Contained Service

Other similar meter forms:
 non-Blondel: 7S, 29S, 36S,
 46S

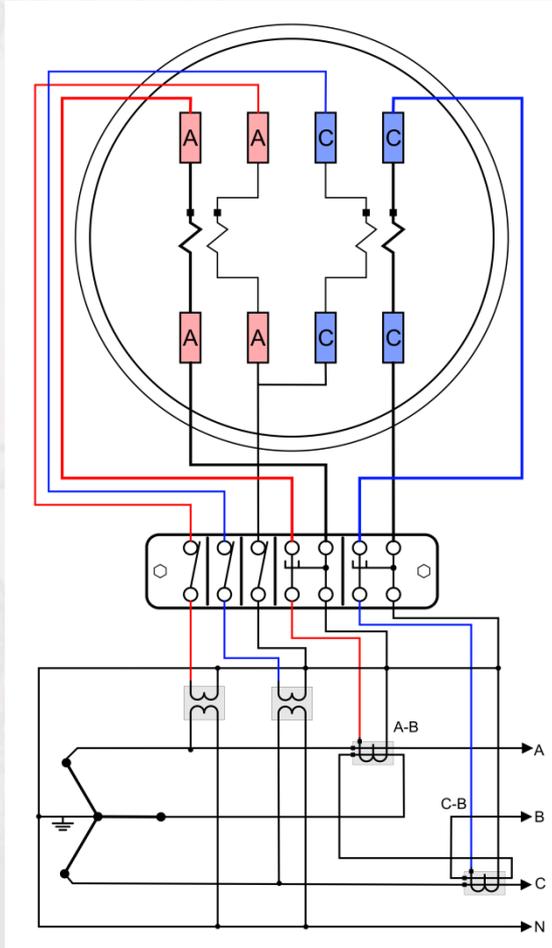
These are non-Blondel metering applications with 2 voltages and 3 currents. The power equation is:

$$P = \vec{V}_{an} \bullet (\vec{I}_a - \vec{I}_b) + \vec{V}_{cn} \bullet (\vec{I}_c - \vec{I}_b)$$

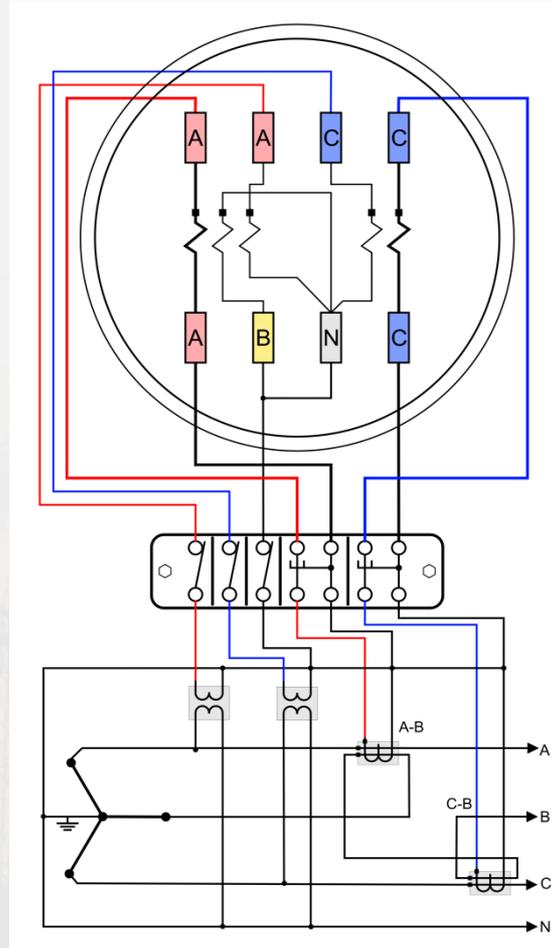


4-Wire Wye Service

3-Phase, 4-Wire Wye 208/480/600V



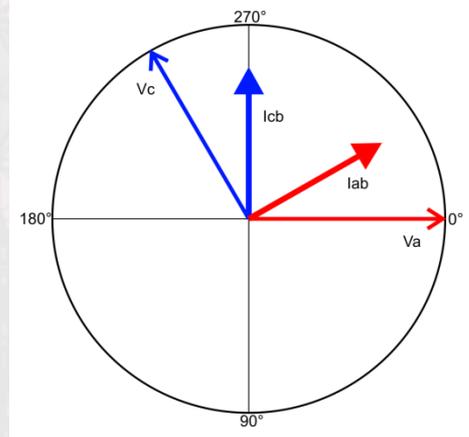
5S Transformer Rated Service



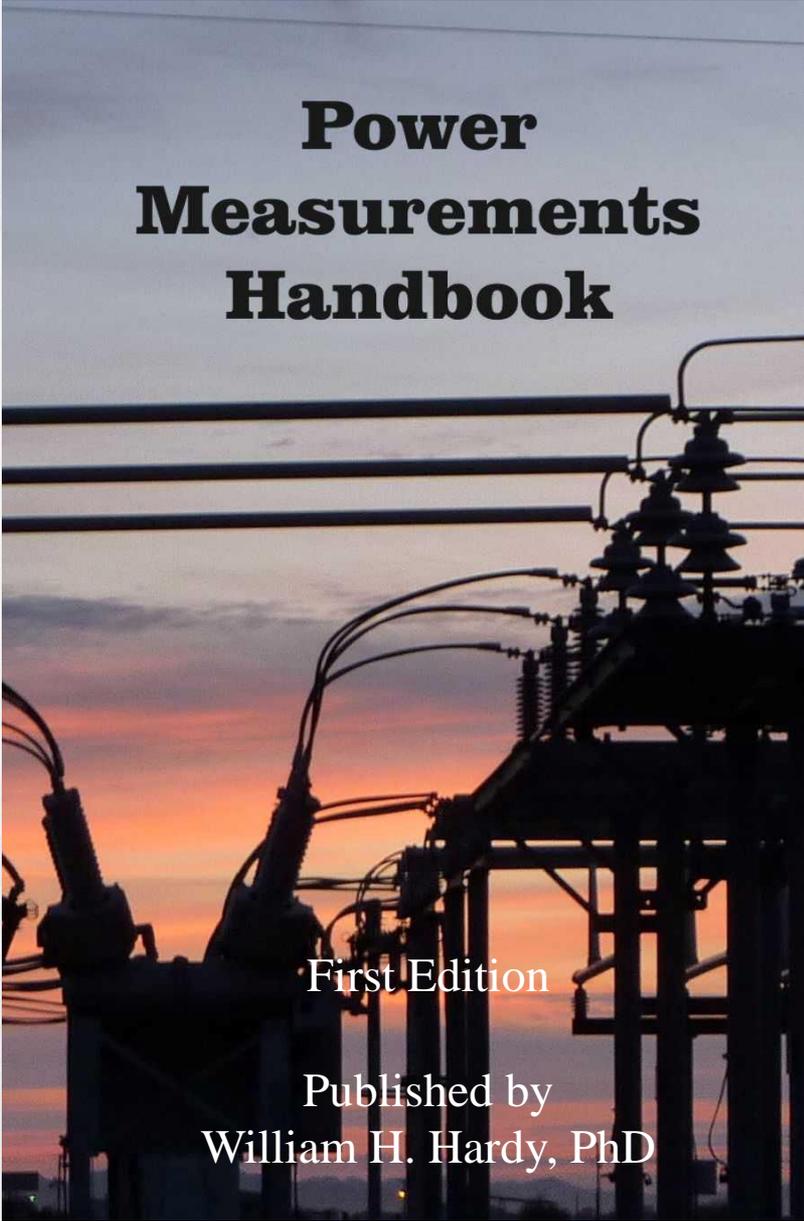
45S Transformer Rated Service

These are non-Blondel metering applications with 2 voltages and 2 currents. The power equation is:

$$P = \vec{V}_{an} \bullet (\vec{I}_a - \vec{I}_b) + \vec{V}_{cn} \bullet (\vec{I}_c - \vec{I}_b)$$



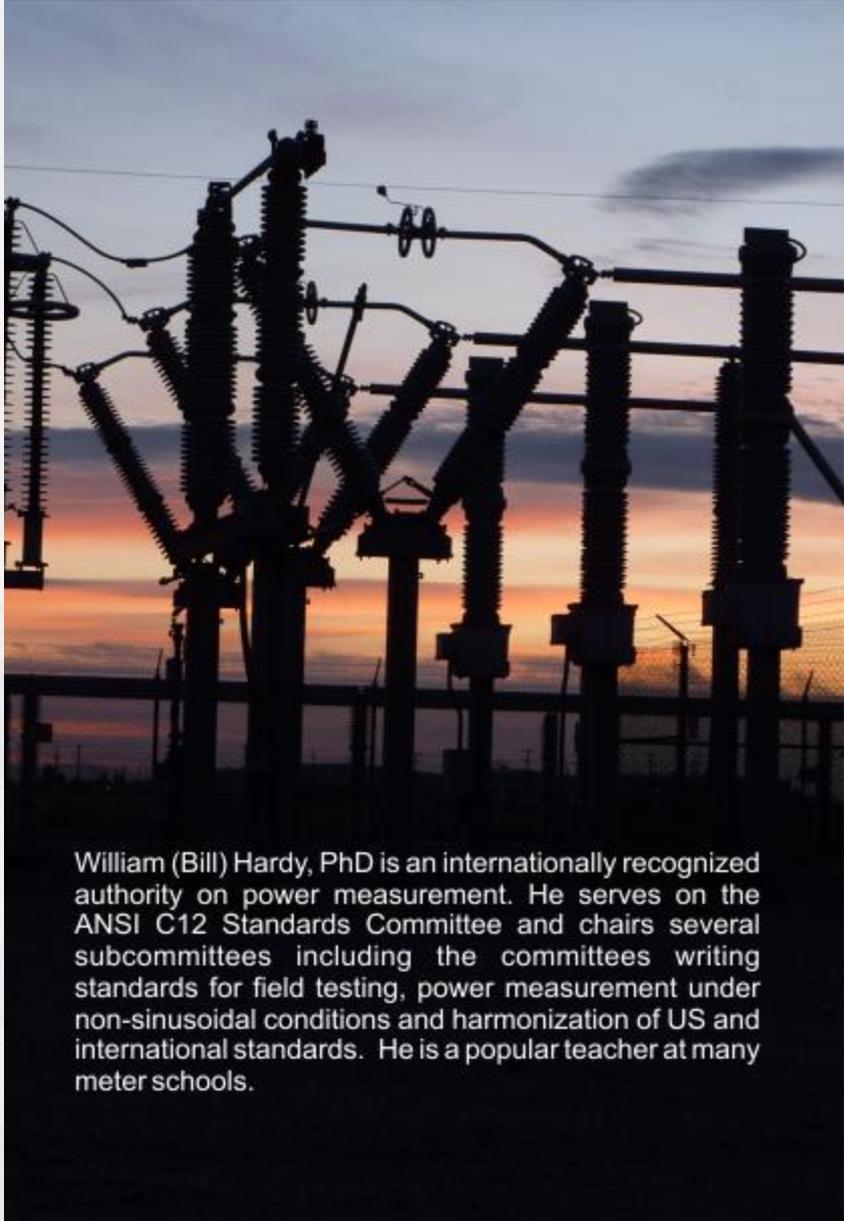
Other similar meter forms:
non-Blondel: 26S, 66S



Power Measurements Handbook

First Edition

Published by
William H. Hardy, PhD



William (Bill) Hardy, PhD is an internationally recognized authority on power measurement. He serves on the ANSI C12 Standards Committee and chairs several subcommittees including the committees writing standards for field testing, power measurement under non-sinusoidal conditions and harmonization of US and international standards. He is a popular teacher at many meter schools.