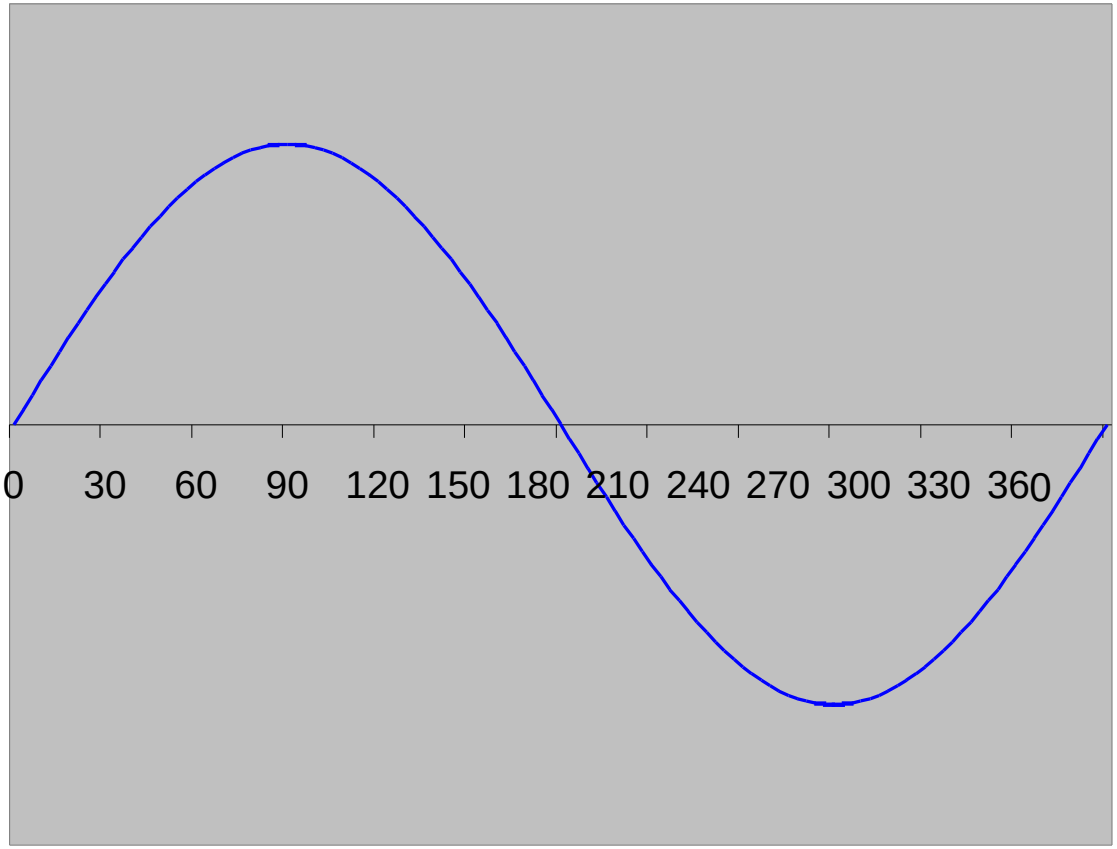
THE EASTERN SPECIALTY COMPANY

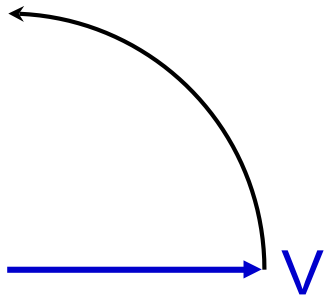
INTRODUCTION TO POLYPHASE METERING

Prepared by Tom Lawton, TESCO

For Mid-South Annual Meter School
May 4, 2022
10:00 AM
Group 2

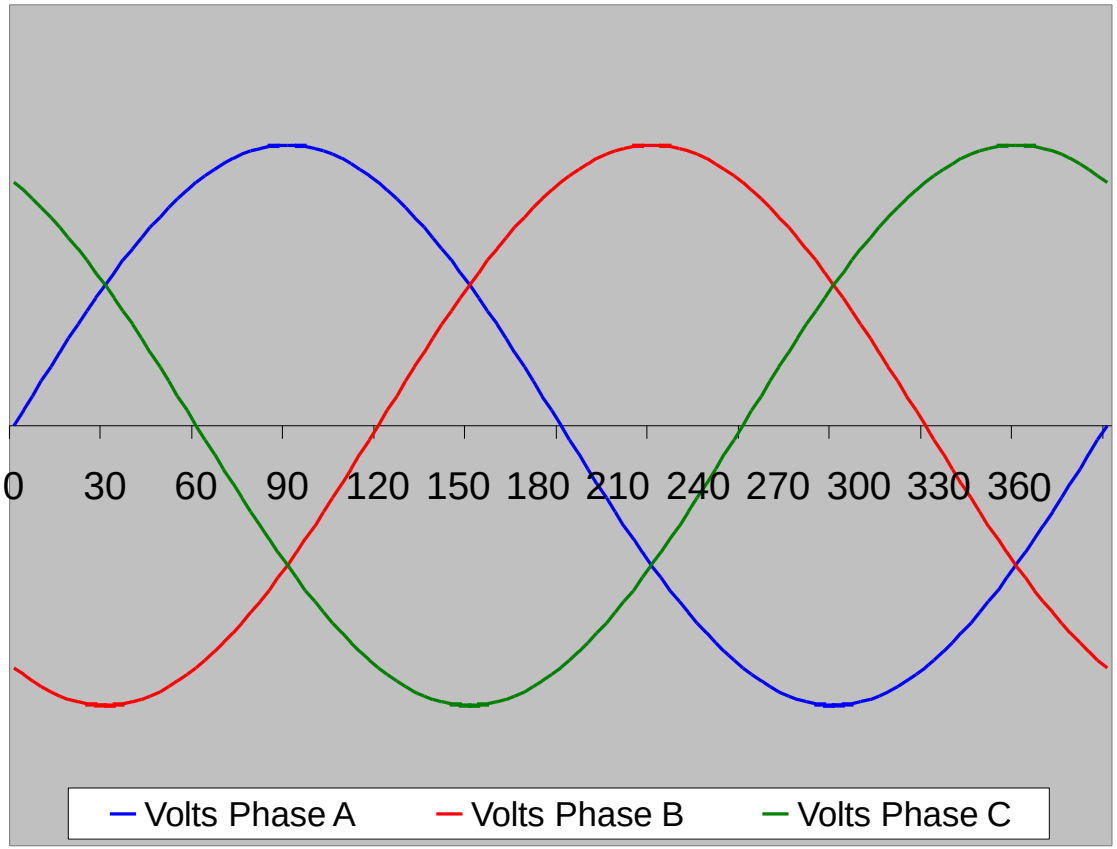
1-Phase and 3-Phase Power

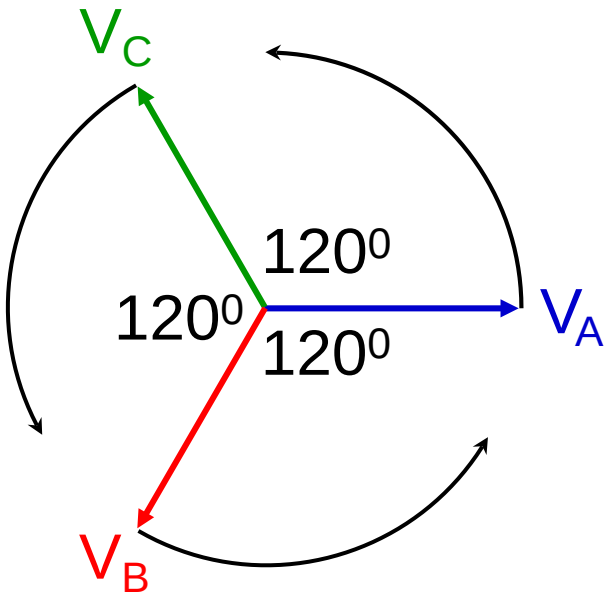




Voltage = V_{max} sine α

1-Phase and 3-Phase Power





Forward Rotation, ABC

The Need for 3-Phase Power

Single-phase motors provide a pulsating torque to a mechanical load. Loads which require more than 10 horsepower generally also require the steadier torque of a 3-phase motor.

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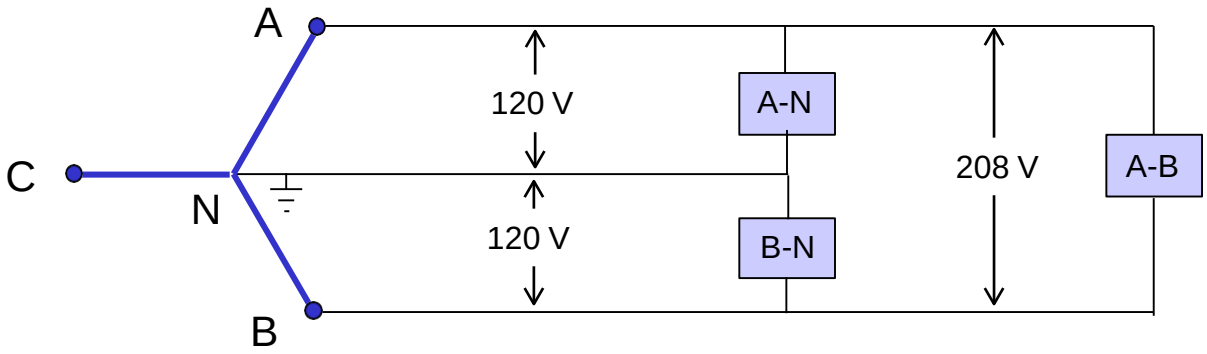
BENEFITS OF 3-PHASE POWER

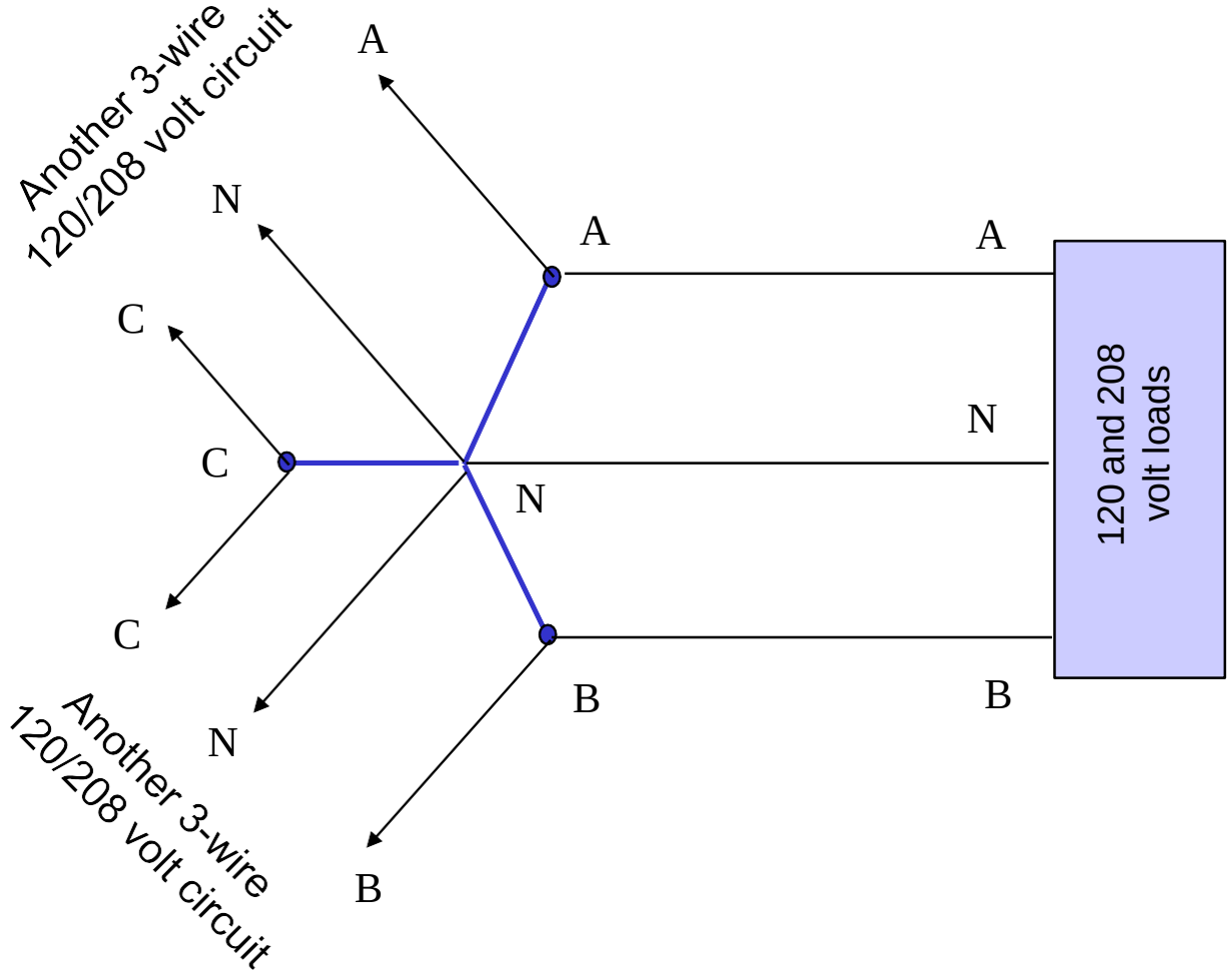
- ✓Steadier motor torque
- ✓Less vibration in machinery
- ✓Greater mechanical efficiency
- ✓Better voltage regulation
- ✓Lower heat losses
- ✓Lighter weight conductors

NETWORK SERVICE & LOADS

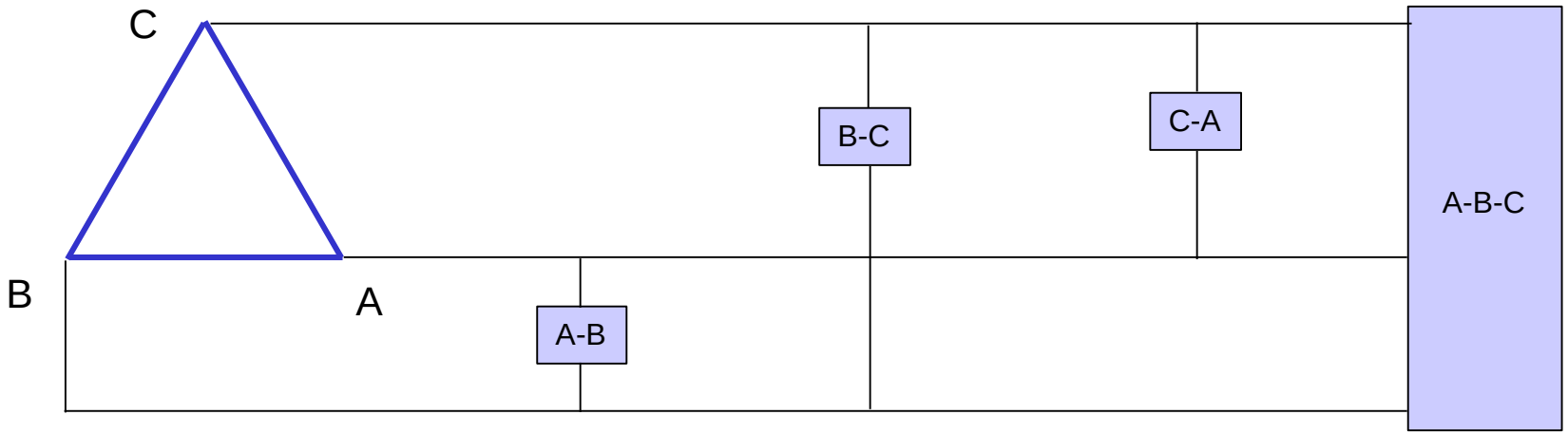


Need to meter line-neutral and line-line loads.

NETWORK SERVICE & LOADS

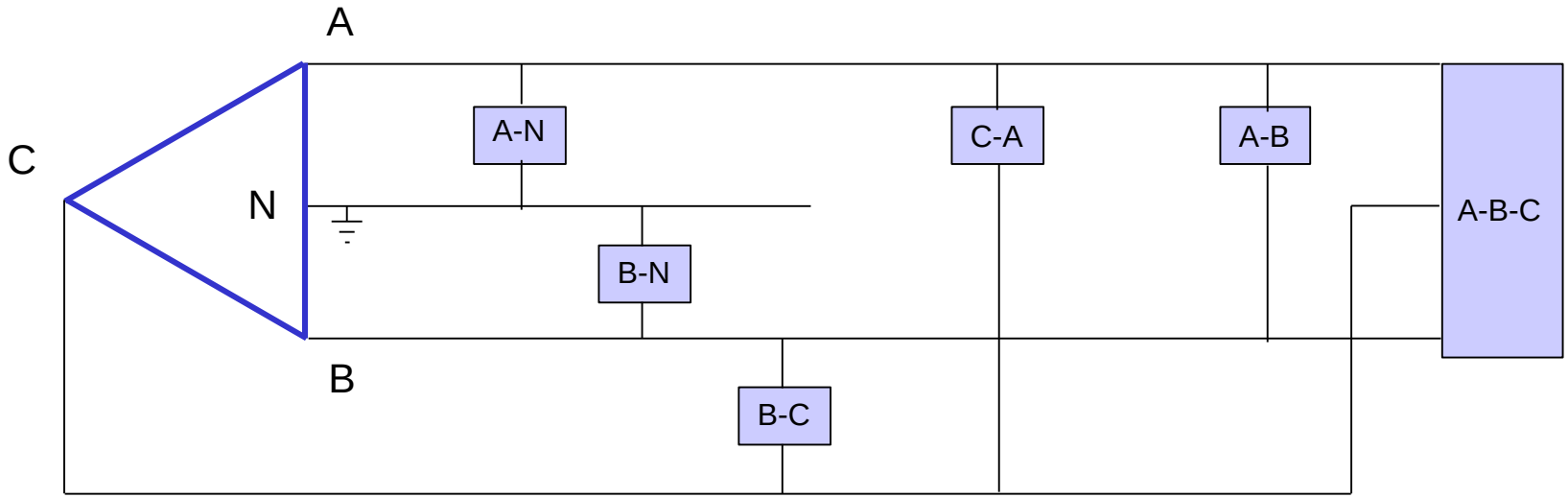


3-Wire Delta Service & Loads



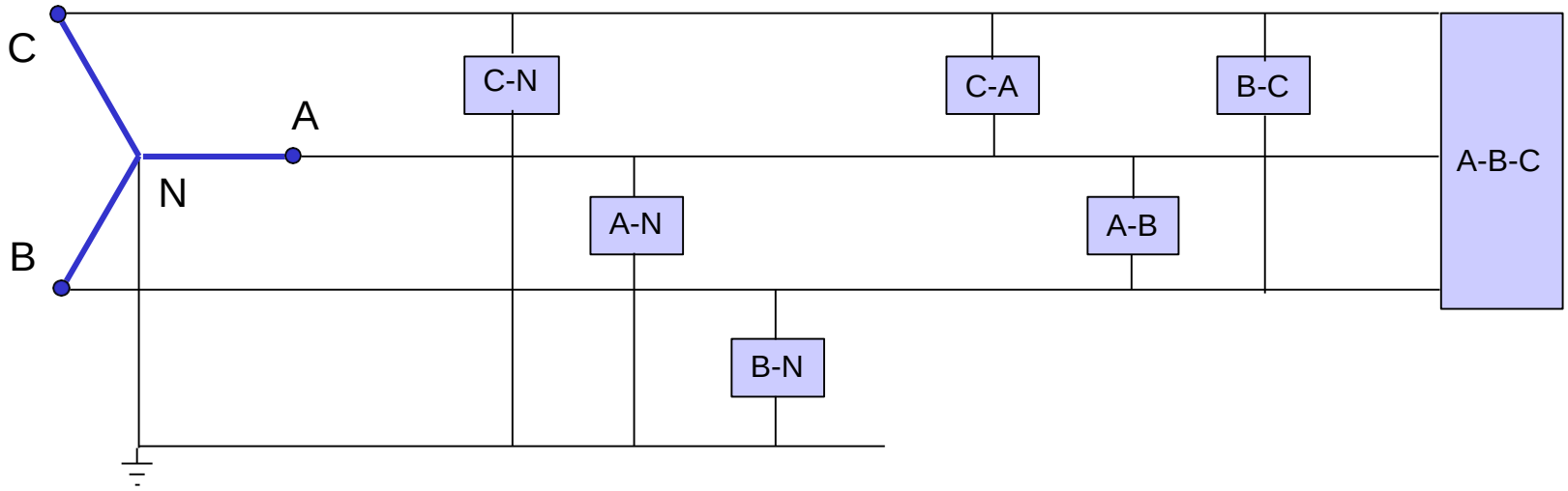
Need to meter single phase line-line loads, as well as three phase loads.

4-Wire Delta Service & Loads



Need to meter single phase line-neutral and line-line loads, as well as three phase loads.

4-Wire Wye Service & Loads



Need to meter single phase line-neutral and line-line loads, as well as three phase loads.

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BLONDEL'S THEOREM

Blondel says:

> If energy is supplied to any system of conductors through N wires, the total power in the system is given by the algebraic sum of readings of N wattmeters, so arranged that each of the N wires contains one current coil, the corresponding potential coil being connected between that wire and some common point. If this common point is on one of the N wires, the measurement may be made by the use of N-1 wattmeters.

Andre E. Blondel, 1893

- We would use "watthour meters" in place of "watt meters" and "energy" in place of "power".
- We would also consider "ground" as a possible current carrying conductor when counting "N".

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BLONDEL'S THEOREM

- In a system of N conductors, N-1 meter elements, properly connected, will measure the power or energy taken. The connection must be such that all voltage coils have a common tie to the conductor in which there is no current coil.[1]

[1] From the Handbook For Electricity Metering, 9th edition.

What is a Meter Form Number?

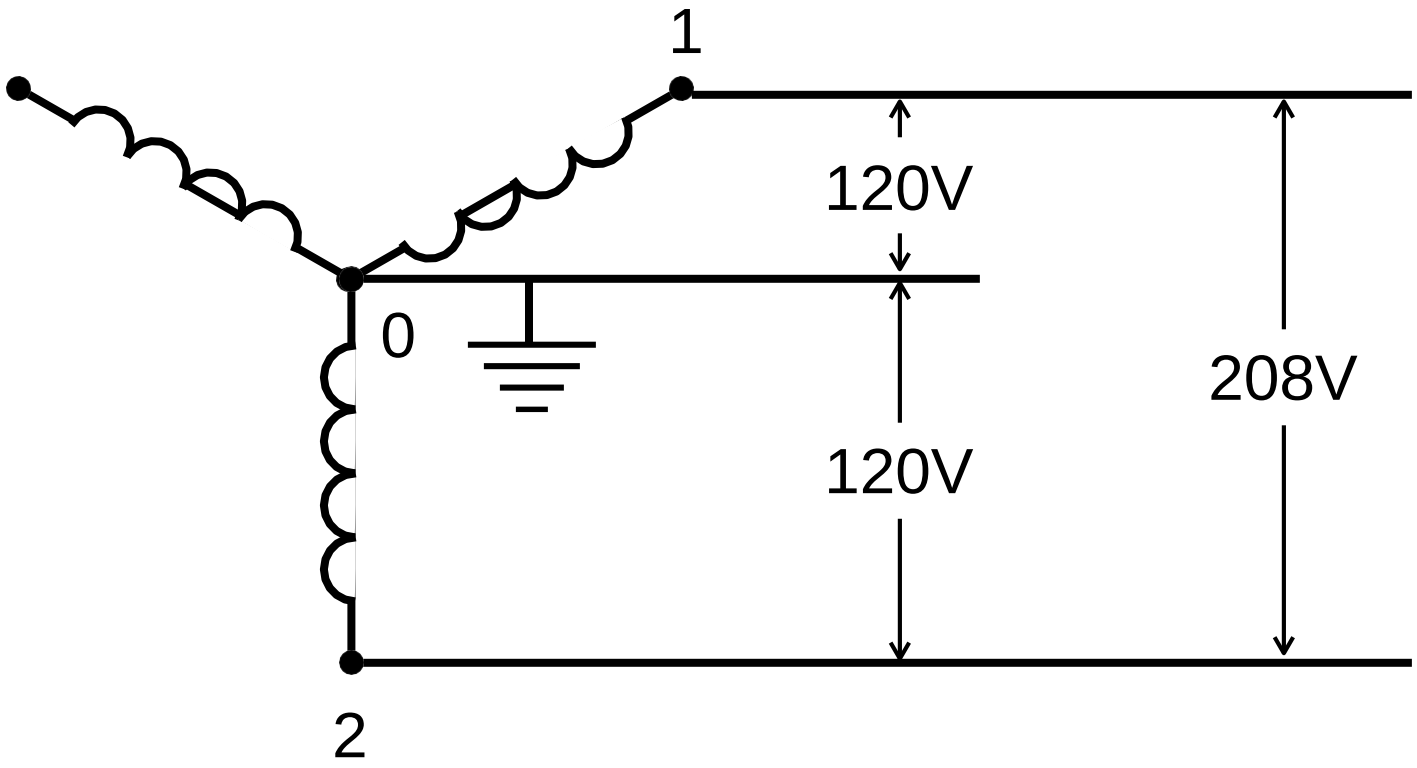
- A Form designation tells us:
  - The number and arrangement of meter terminals, and
  - The number and ***internal connection*** of meter elements (stators).
- The Form designation describes the meter, not the service.
  - With modern meters, some meter Forms may be used to correctly meter more than one service configuration.
  - More than one meter Form could be used with a particular service depending on the connection of the Instrument Transformers.
- The same Form designation is usually applicable to equivalent meters of all manufacturers.

WILL'S METER FORMS CHEAT SHEET

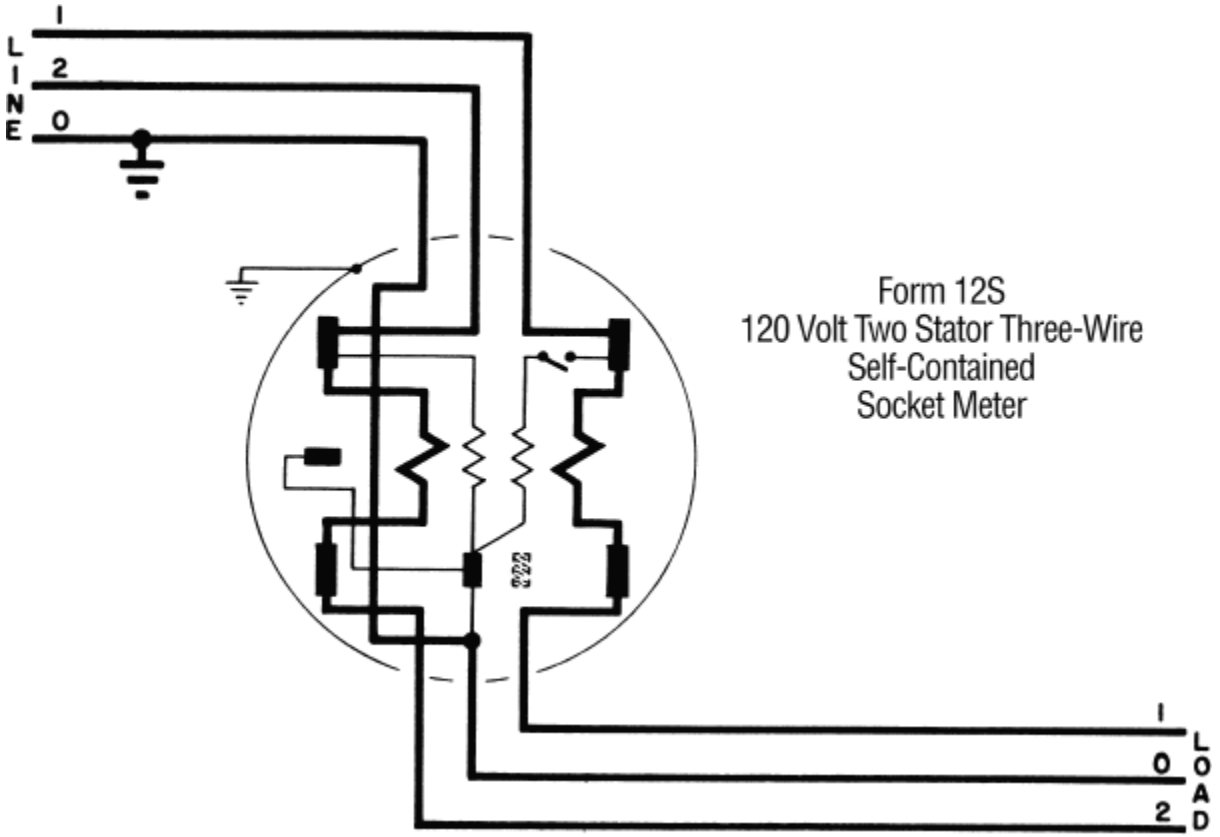
SERVICE	SELF-CONT FORM	XFMR-RATD FORM	NUMBER OF ELEMENTS
1-Phase, 2-Wire	1S	3S	1
1-Phase, 3-Wire	2S	4S	1.5
Network, 3-Wire	12S	5S / 45S	2
3-Phase, 3-Wire, Delta			
3-Phase, 4-Wire, Delta	15S	8S	2.5
3-Phase, 4-Wire, Wye	14S	6S / 36S	
	16S	9S	3

Consolidated by kV2c Form 16S	Consolidated by kV2c Form 9S	Blondel Solution

NETWORK, 3-WIRE



NETWORK, 3-WIRE



Form 12S
120 Volt Two Stator Three-Wire
Self-Contained
Socket Meter

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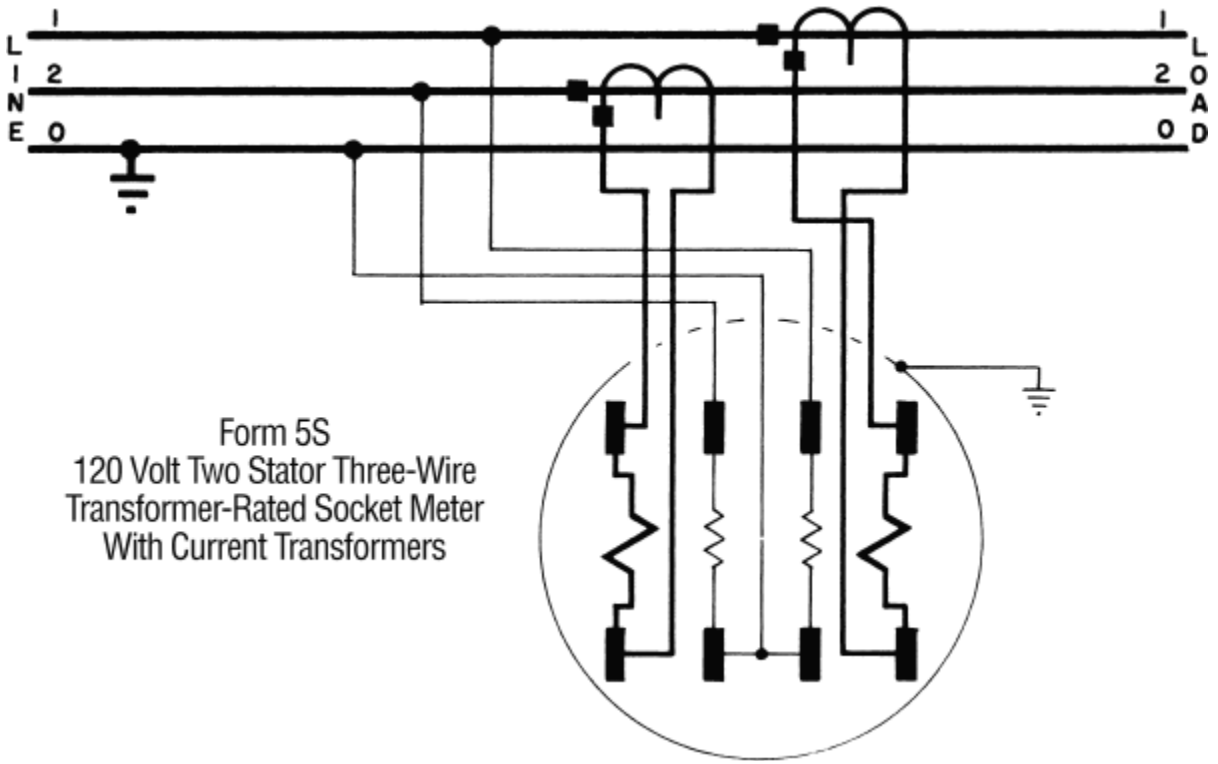
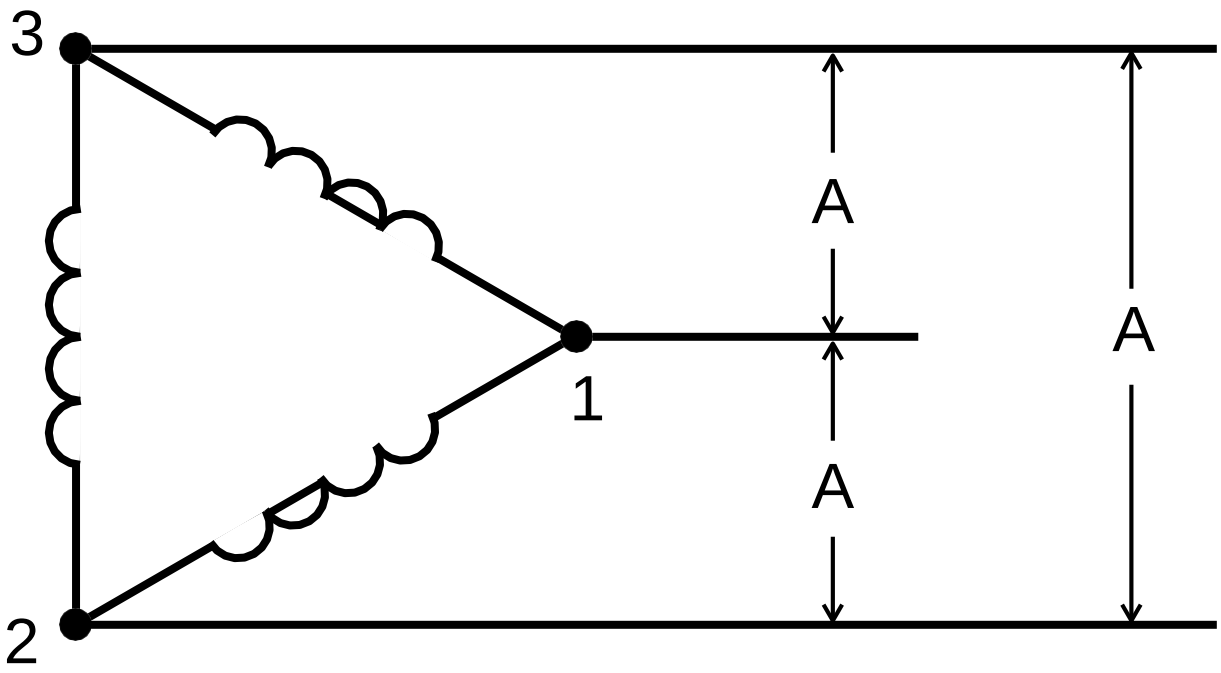
NETWORK, 3-WIRE



Form 5S
120 Volt Two Stator Three-Wire
Transformer-Rated Socket Meter
With Current Transformers

3-Phase, 3-Wire, Delta



A = 120V, 240V, or 480V

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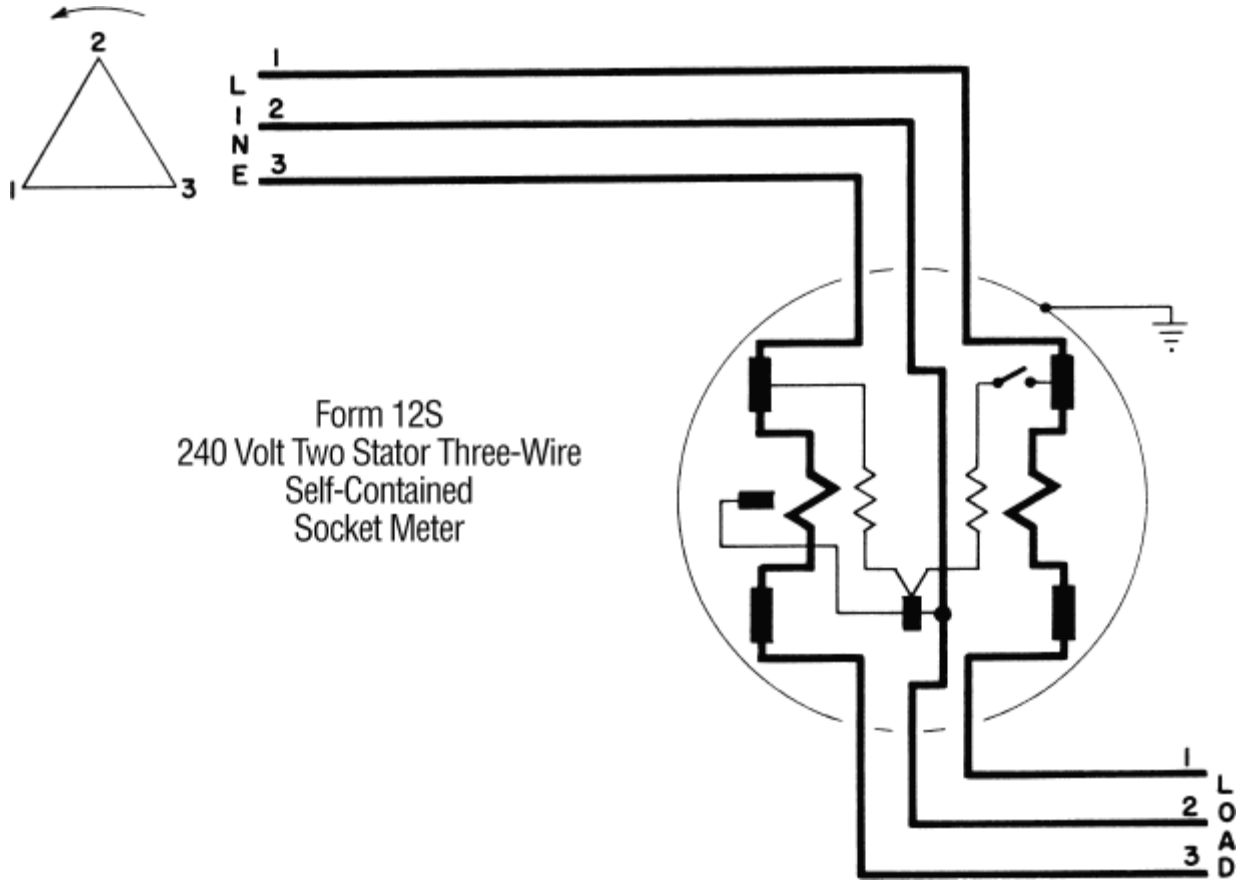
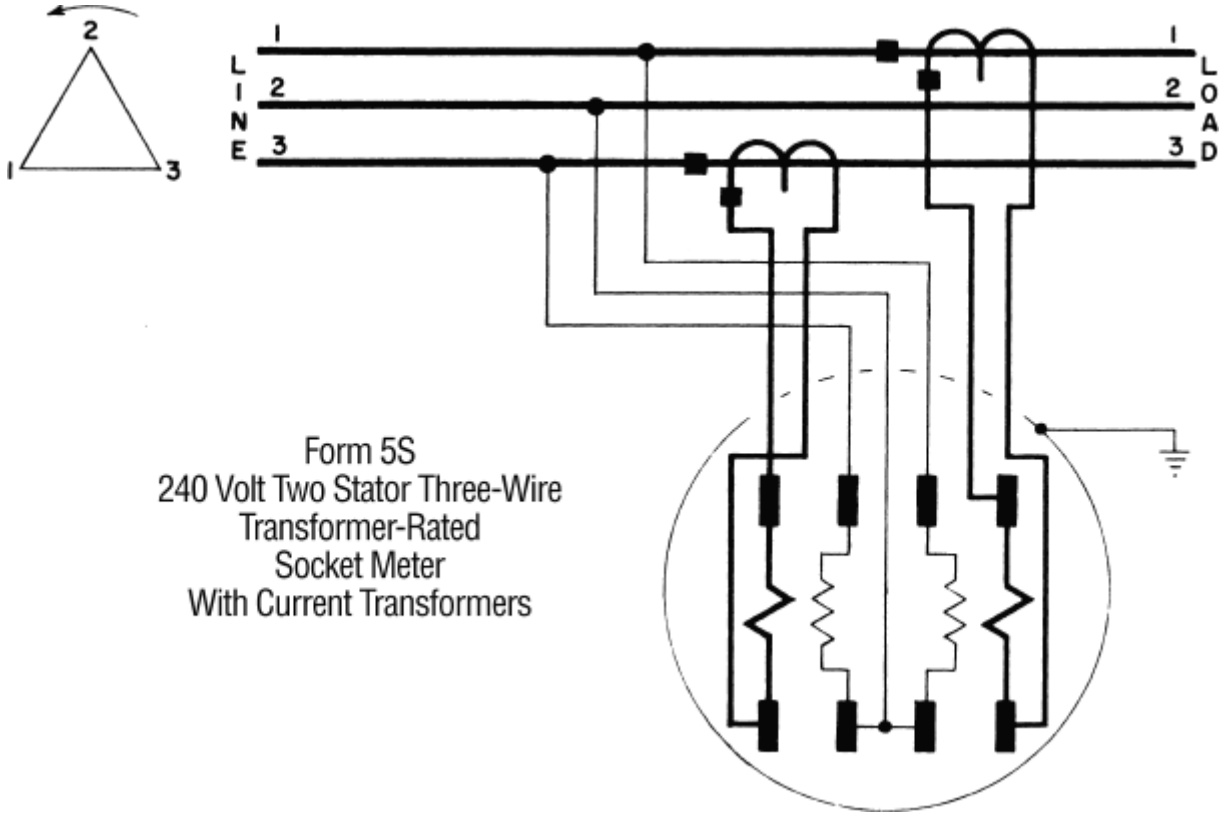
3-PHASE, 3-WIRE, DELTA



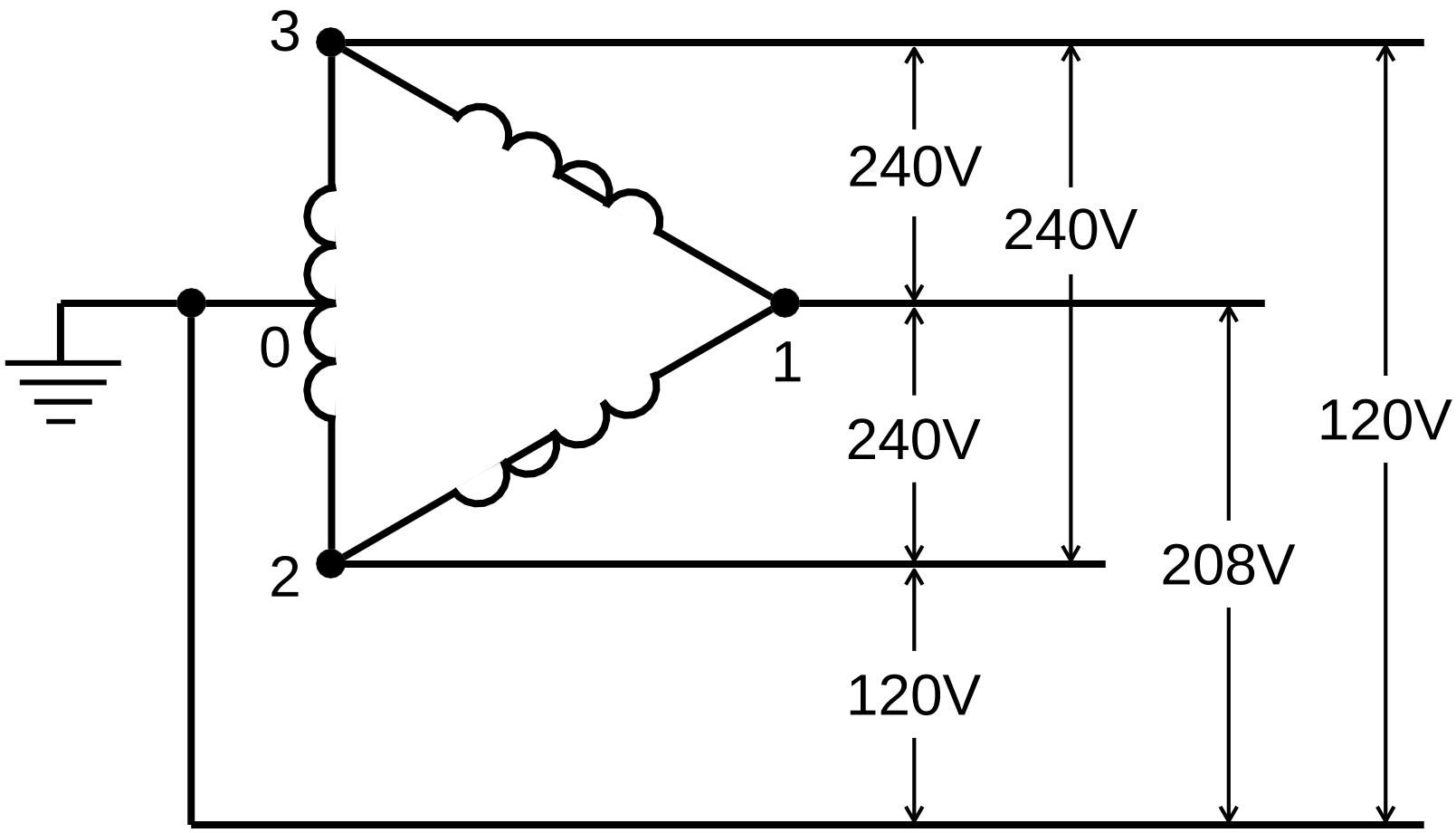
Form 12S
240 Volt Two Stator Three-Wire
Self-Contained
Socket Meter

3-PHASE, 3-WIRE, DELTA

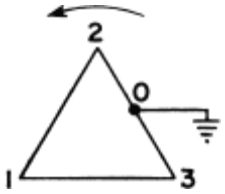


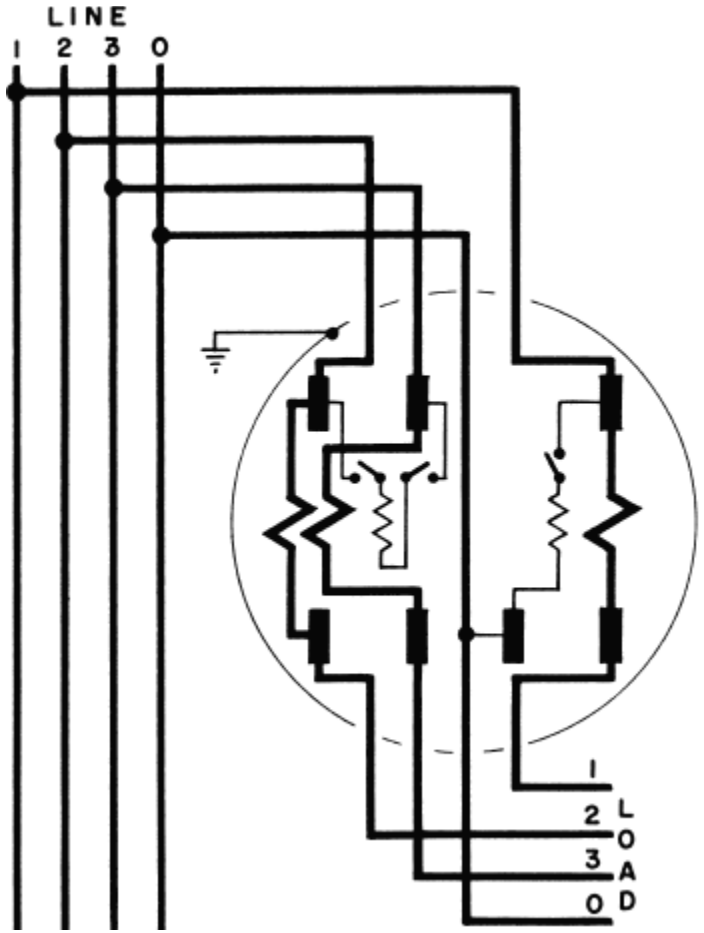
Form 5S
240 Volt Two Stator Three-Wire
Transformer-Rated
Socket Meter
With Current Transformers

3-Phase, 4-Wire, Delta



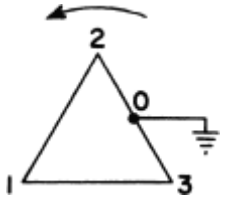
3-Phase, 4-Wire, Delta

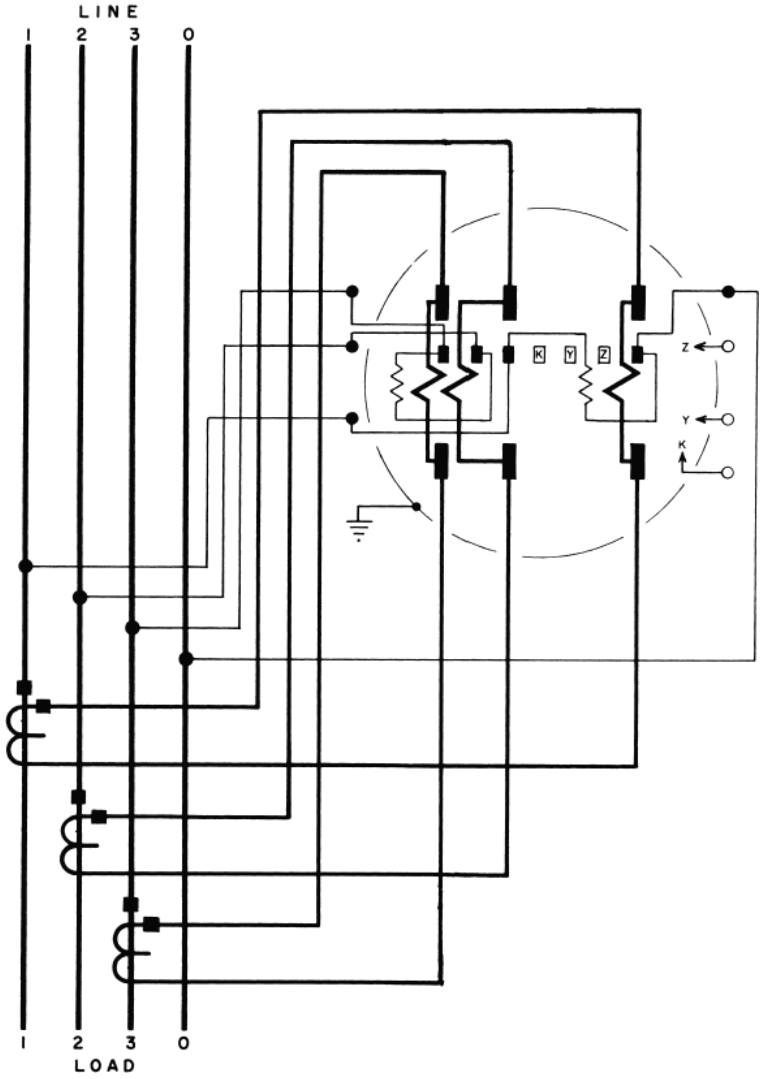




Form 15S
240 Volt Two Stator Four-Wire
Self-Contained
Socket Meter

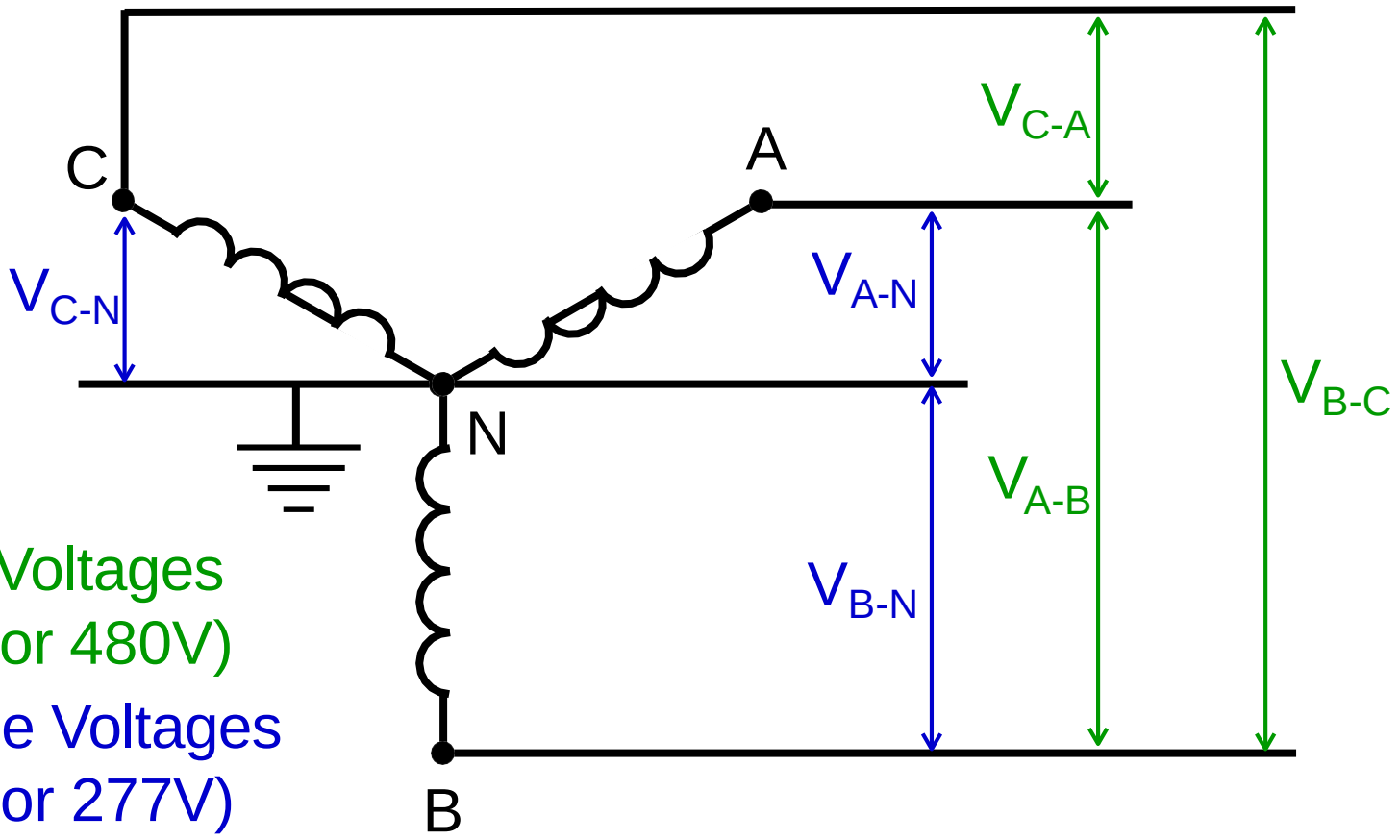
3-Phase, 4-Wire, Delta





Form 8S
240 Volt Two Stator Four-Wire
Transformer-Rated
Socket Meter
With Current Transformers

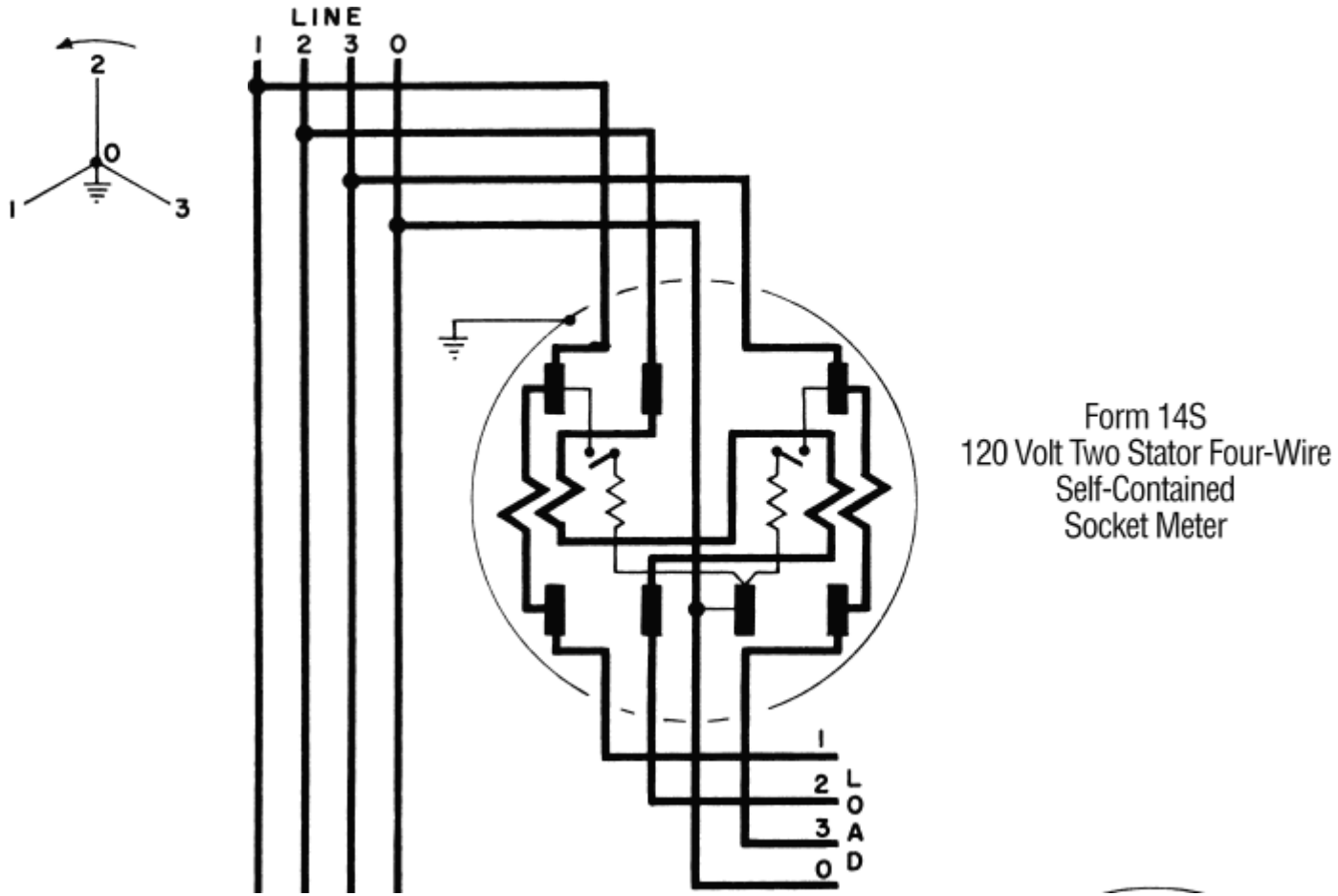
3-Phase, 4-Wire, Wye



Line Voltages
(208 or 480V)

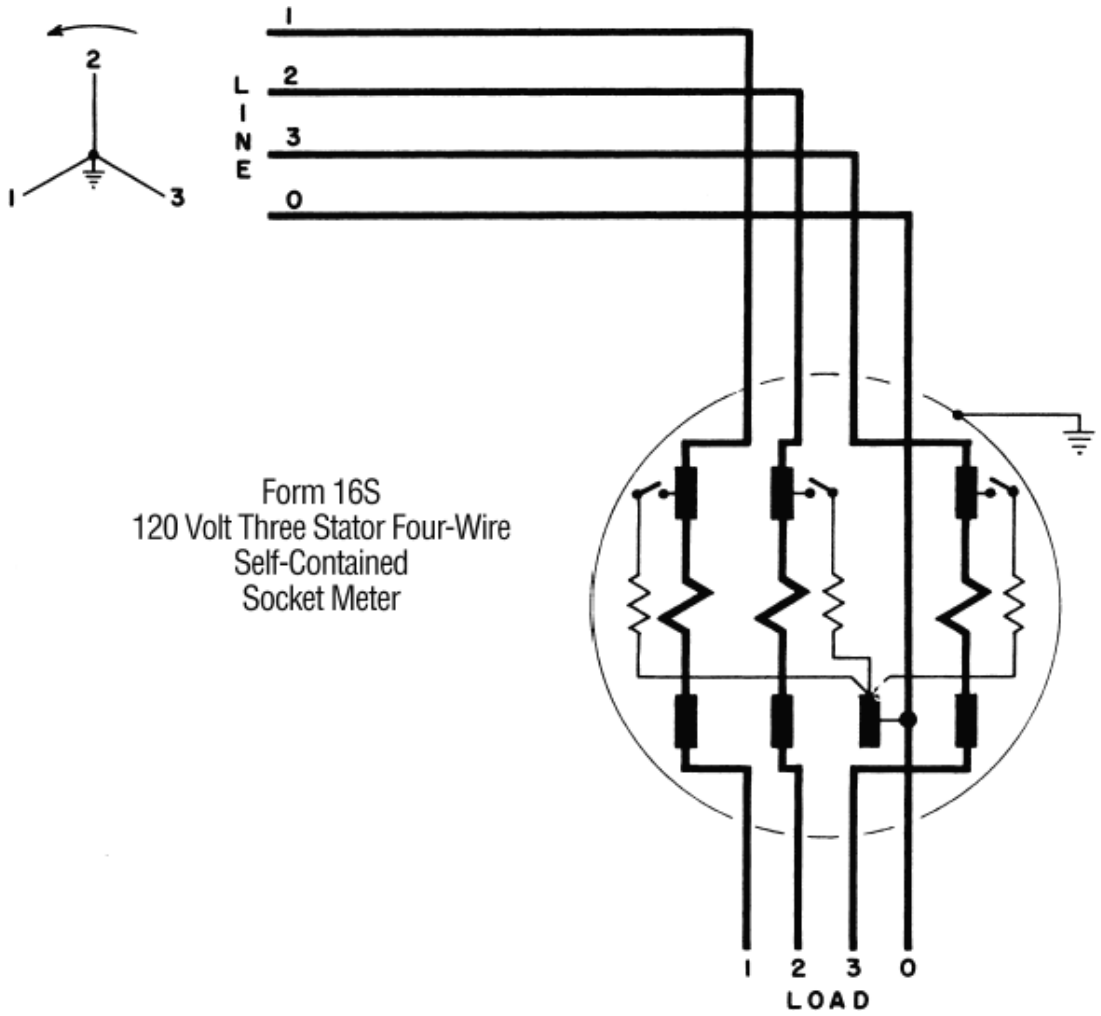
Phase Voltages
(120 or 277V)

3-Phase, 4-Wire, Wye



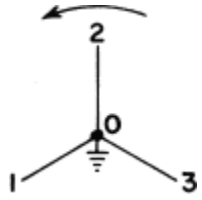
Form 14S
120 Volt Two Stator Four-Wire
Self-Contained
Socket Meter

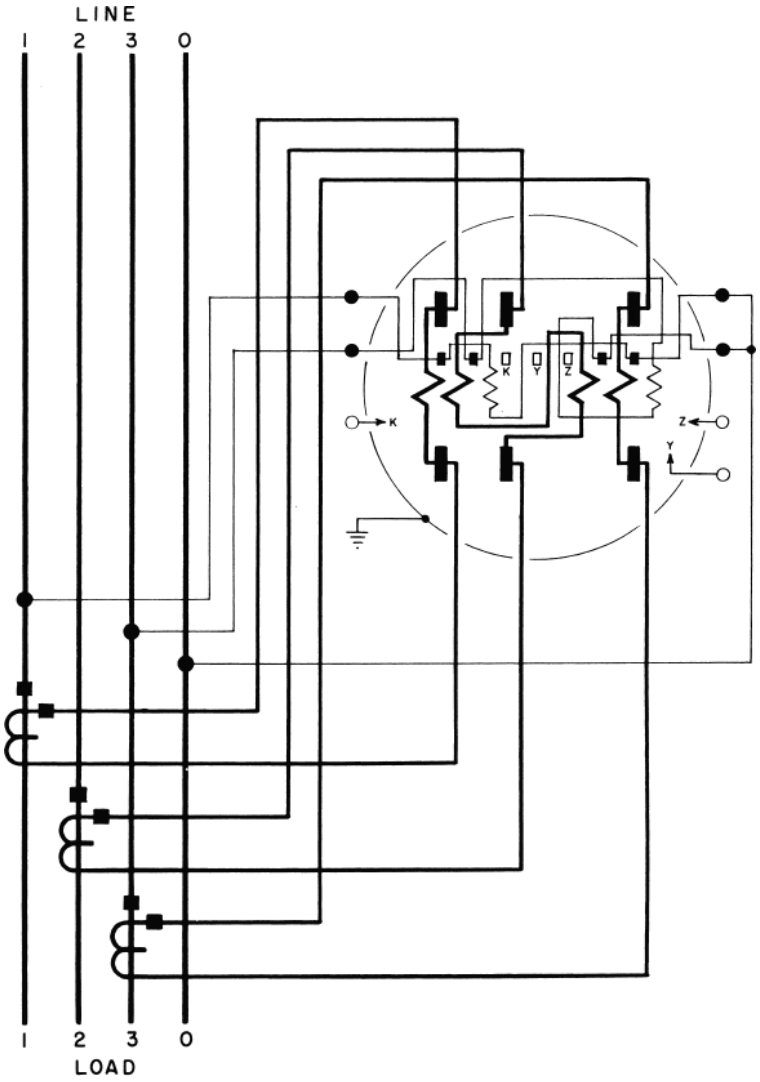
3-Phase, 4-Wire, Wye



Form 16S
120 Volt Three Stator Four-Wire
Self-Contained
Socket Meter

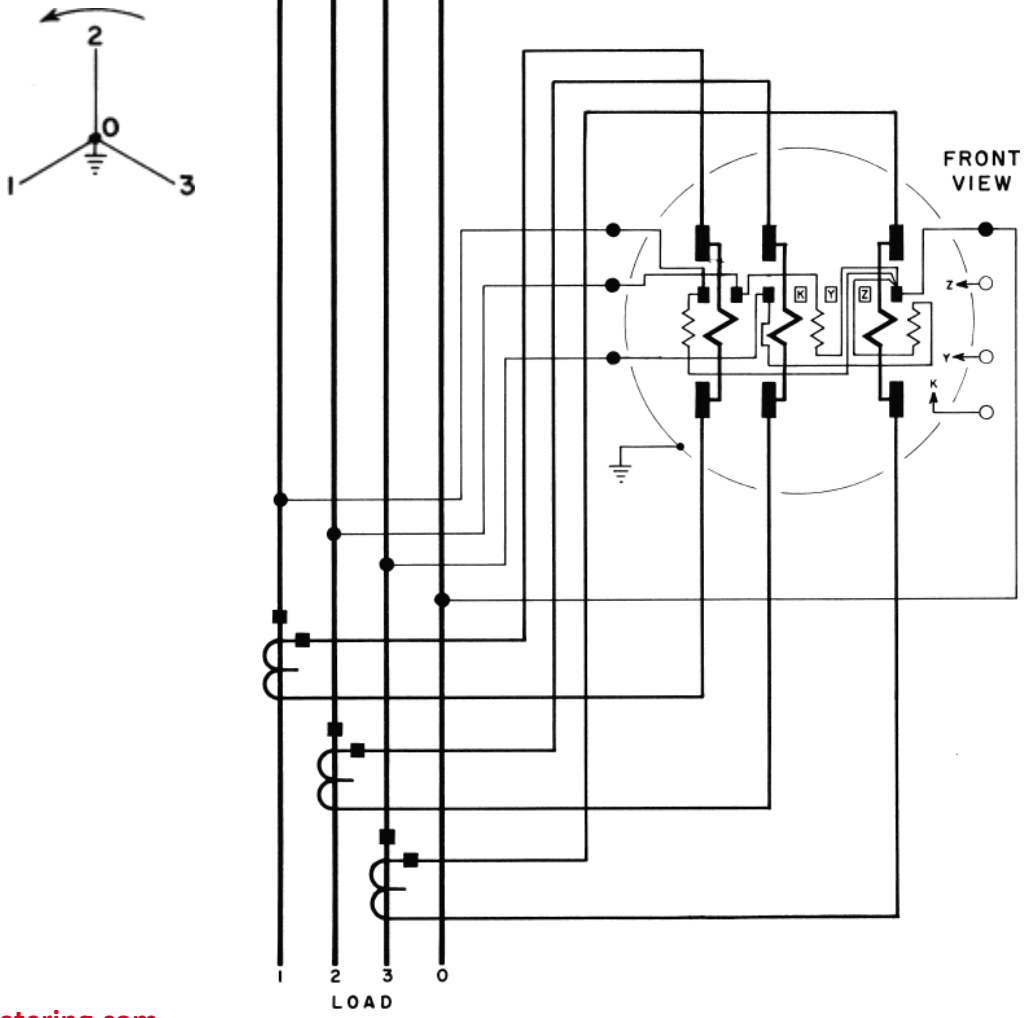
3-Phase, 4 Wire, Wye





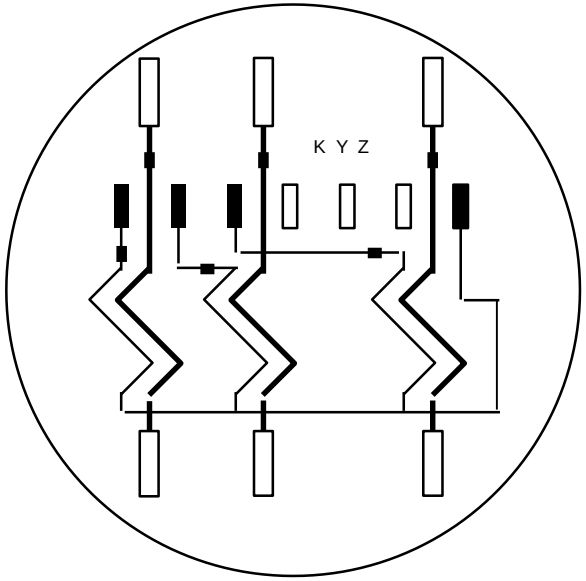
Form 6S
120 Volt Two Stator Four-Wire
Transformer-Rated
Socket Meter
With Current Transformers

3-PHASE, 4-WIRE, WYE



Form 9S
120 Volt Three Stator Four-Wire
Transformer-Rated
Socket Meter
With Current Transformers

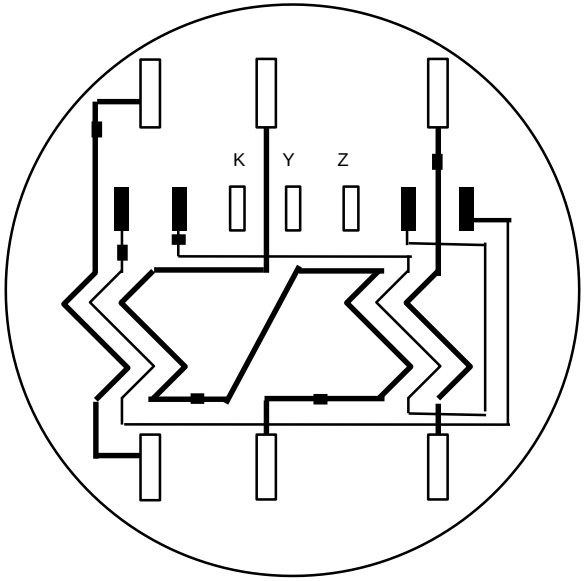
4-Wire Wye Metering



Form 9

3 Element,

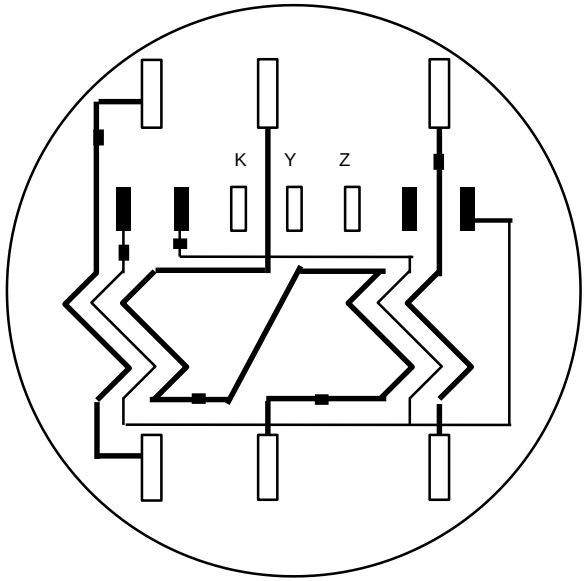
4 wire, wye



Form 6

2½ Element,

4 wire, wye



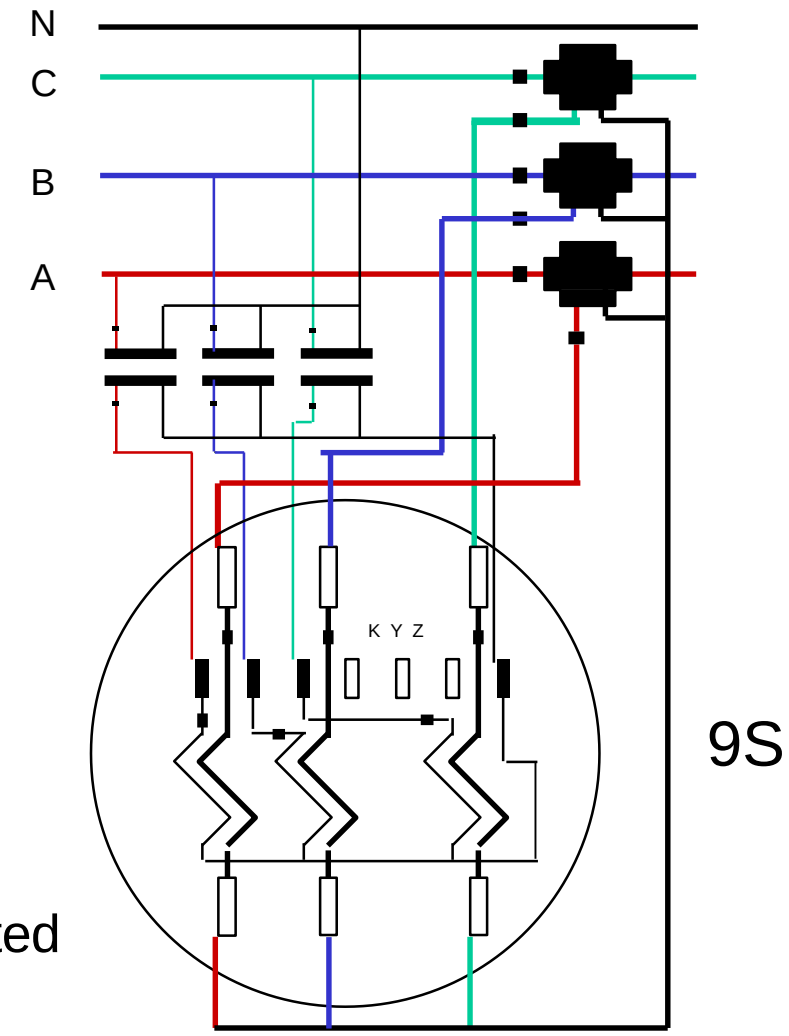
Form 36

2½ Element,

4 wire, wye

Transformer-rated

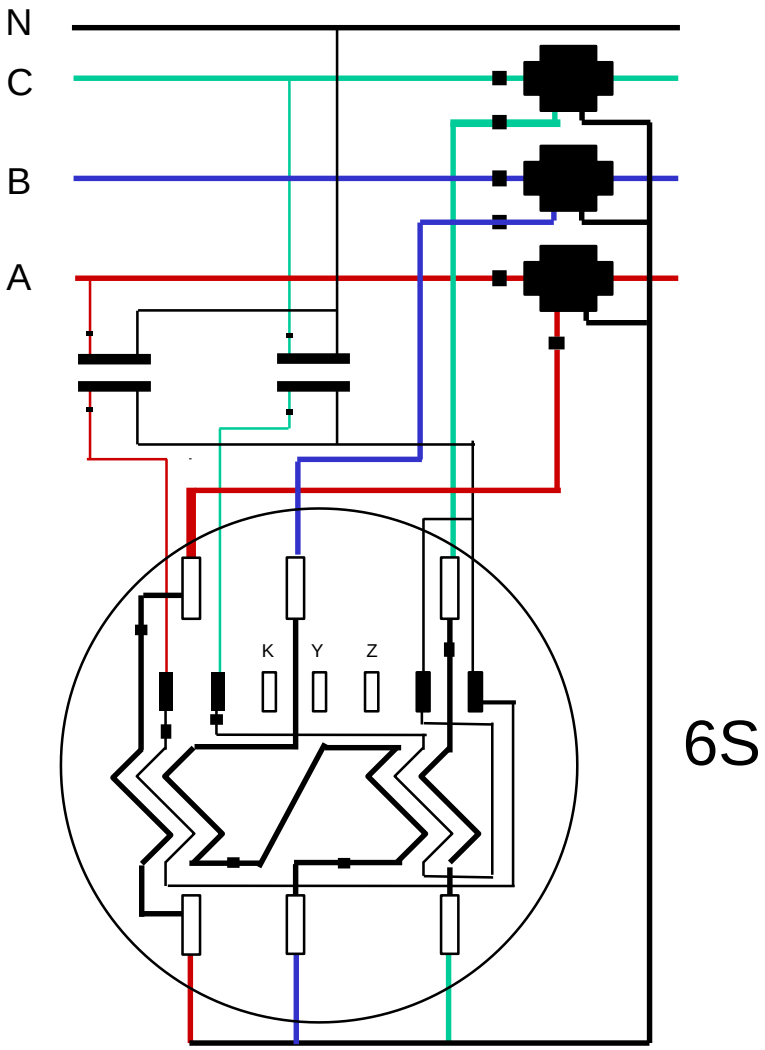
4-Wire, Wye Metering



9S

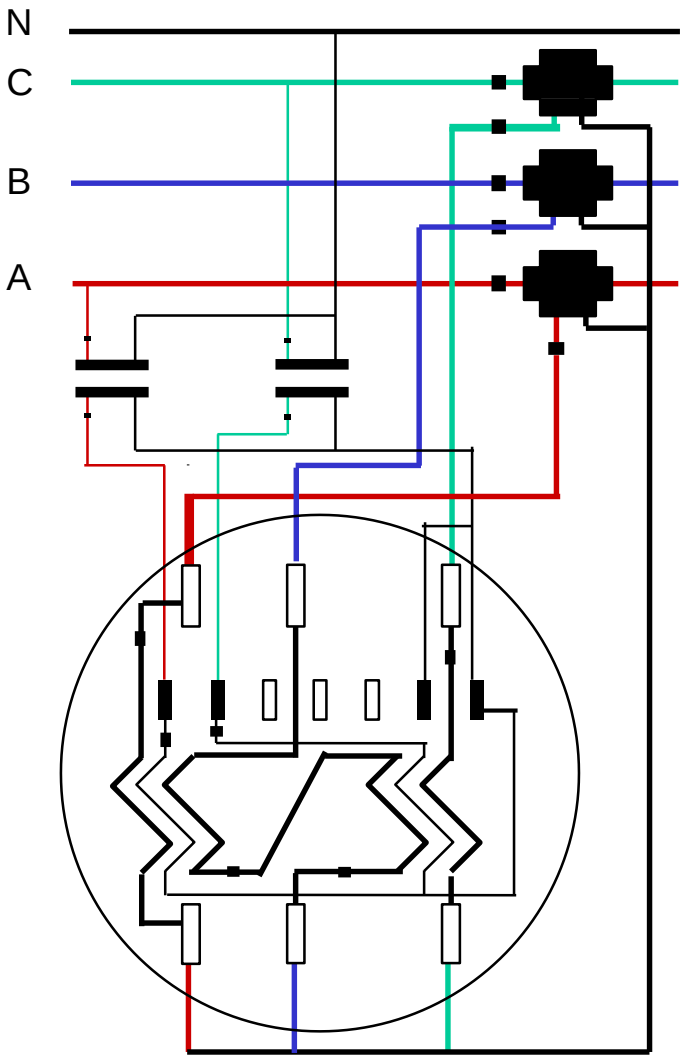
Transformer-rated

4-Wire, Wye Metering



Transformer-rated

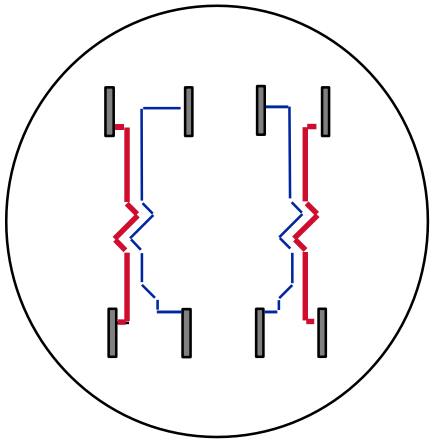
4-Wire, Wye Metering



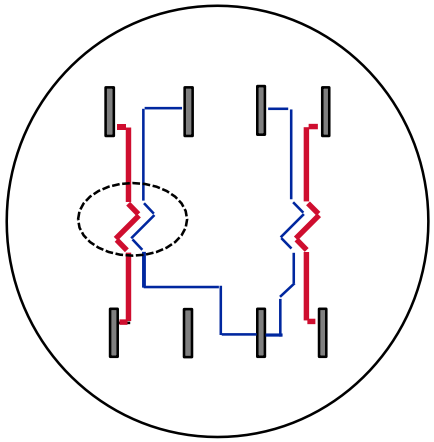
36S

Transformer-rated

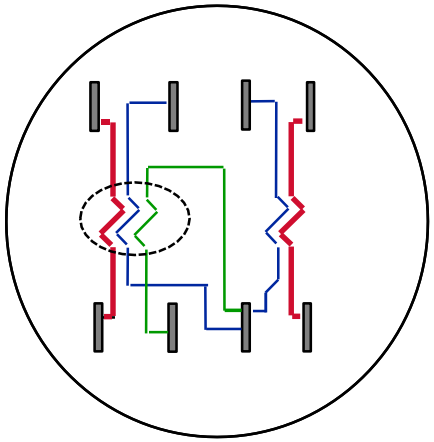
2 Element Meters



Form 5



Form 35



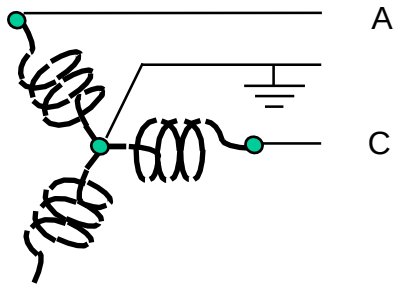
Form 45

Typically used for 3 wire Network or 3 wire, 3 phase Delta applications

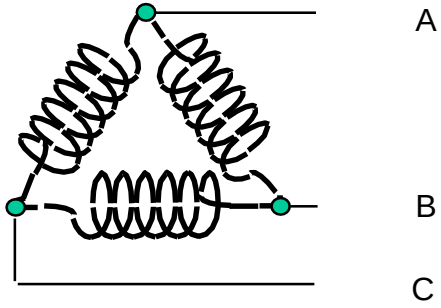
Occasionally used for other service types including 2 wire single phase, 4 wire Wye and 4 wire Delta (except Fm 35 not for 4W Delta)

Transformer-rated

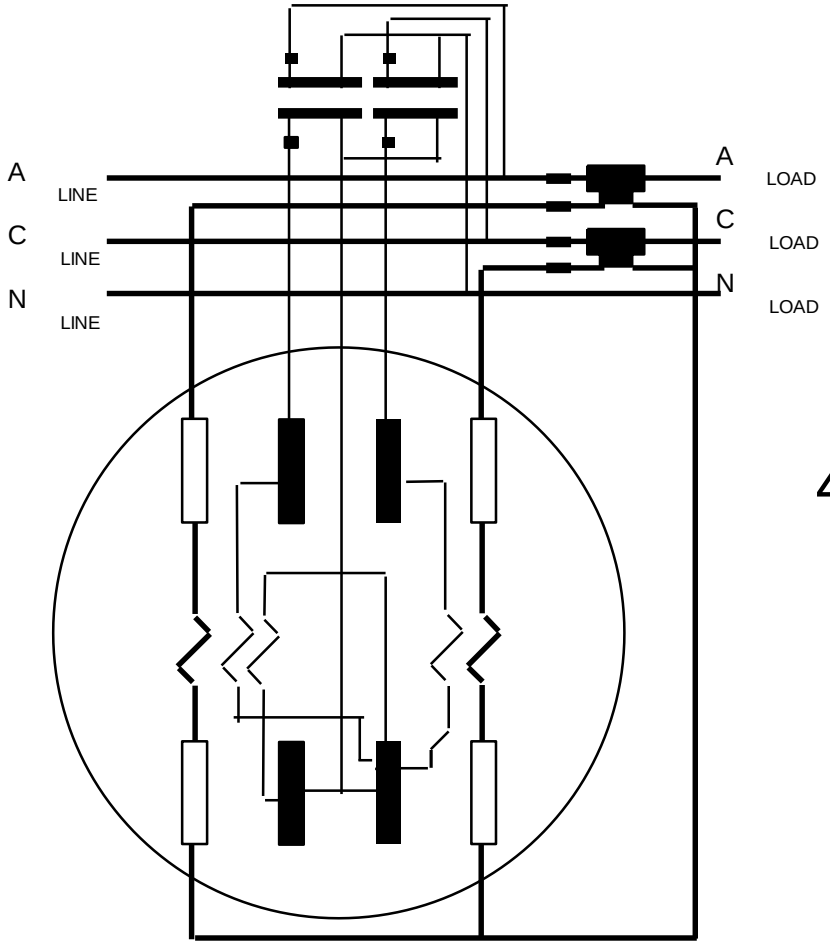
2 Element Meters



3 wire, network



3 wire, delta



45S

POLYPHASE METERS

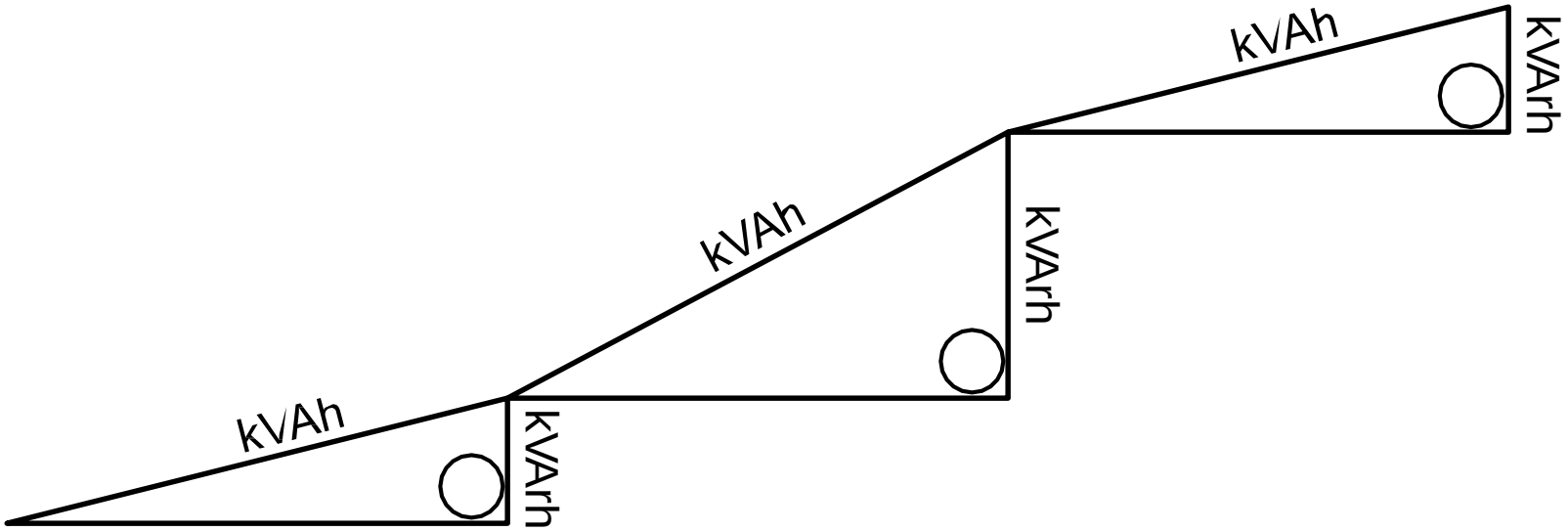
Other Considerations

- Meter Multipliers
  - Self Contained: The meter multiplier is 1
  - Transformer Rated: The multiplier is (typically) the product of the CT and VT ratio
- Service Types
  - Some polyphase meters may be used in multiple service types
- Selection
  - Proper wiring and form selection is critical

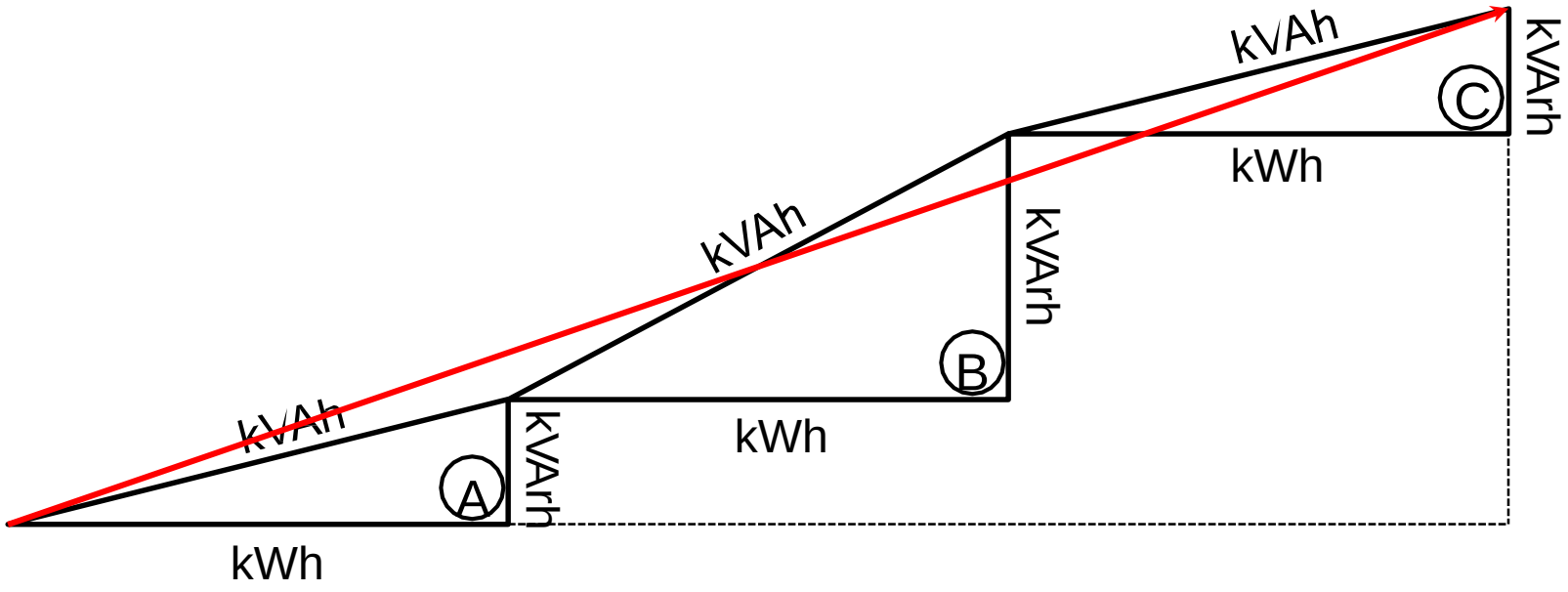
POLYPHASE METERS

- Select the meter based on the source, not the load.
  - The “service type” is not always obvious.
  - Loads other than the “known” load can be connected and may be unmetered.
- Meter form numbers describe certain meter characteristics not the service or application
- Consider that *ground* can be a current carrying conductor when applying Blondel’s Theorem.
- Understand the operation of present day, polyphase solid state meters and how they may be used to advantage

COMBINING POLYPHASE kVAh



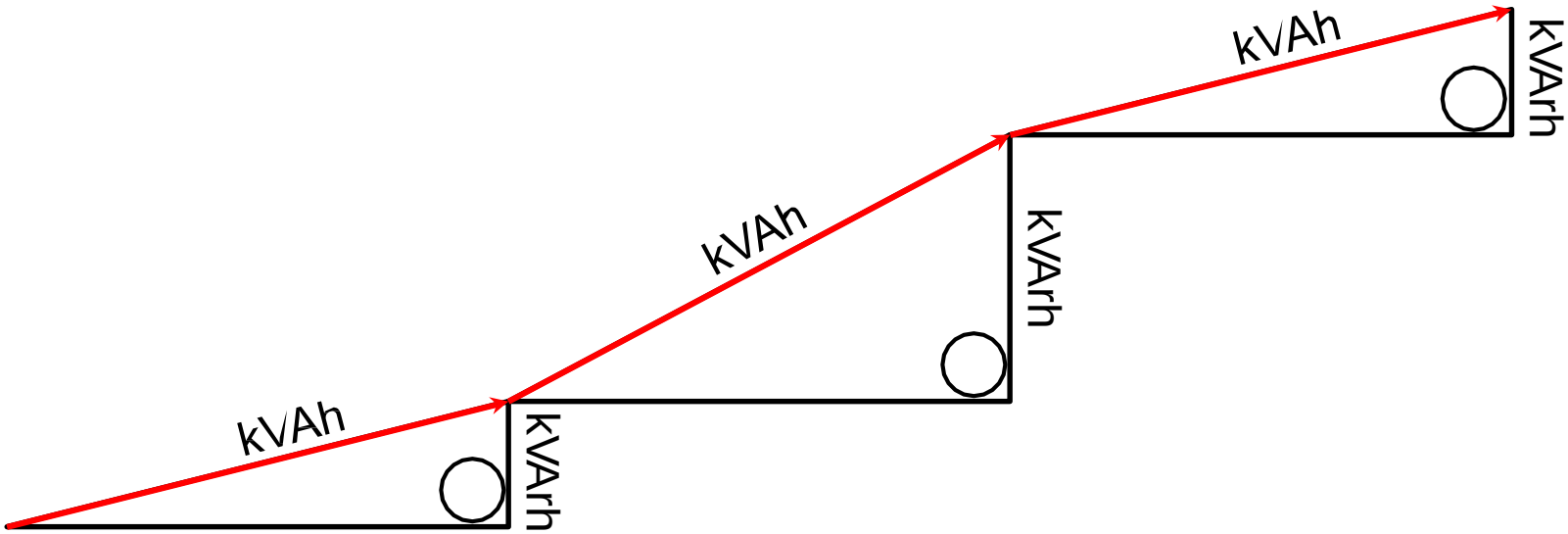
COMBINING POLYPHASE kVAh



Vectoral Method (as the crow flies):

$$\sqrt{(kWh_A + kWh_B + kWh_C)^2 + (kVArh_A + kVArh_B + kVArh_C)^2}$$

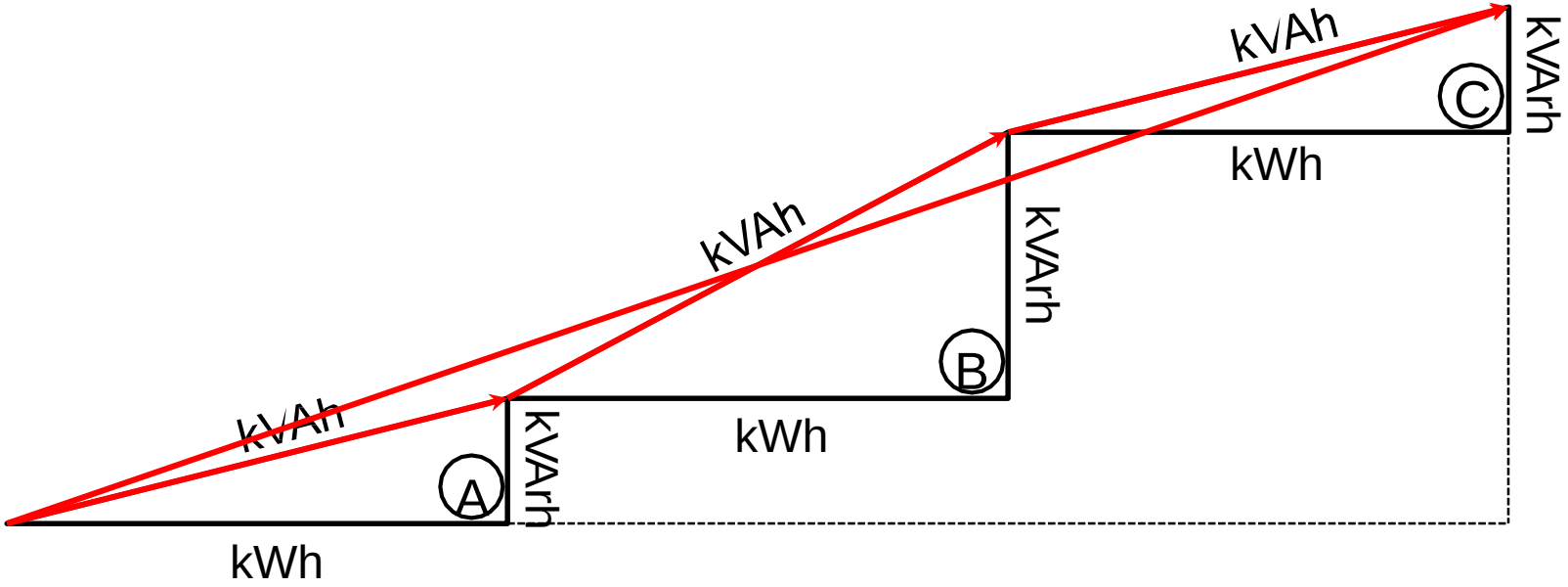
COMBINING POLYPHASE kVAh



Arithmetic Method:

$$\sqrt{kWh_A^2 + kVArh_A^2} + \sqrt{kWh_B^2 + kVArh_B^2} + \sqrt{kWh_{C_2} + kVArh_{C_2}}$$

COMBINING POLYPHASE kVAh



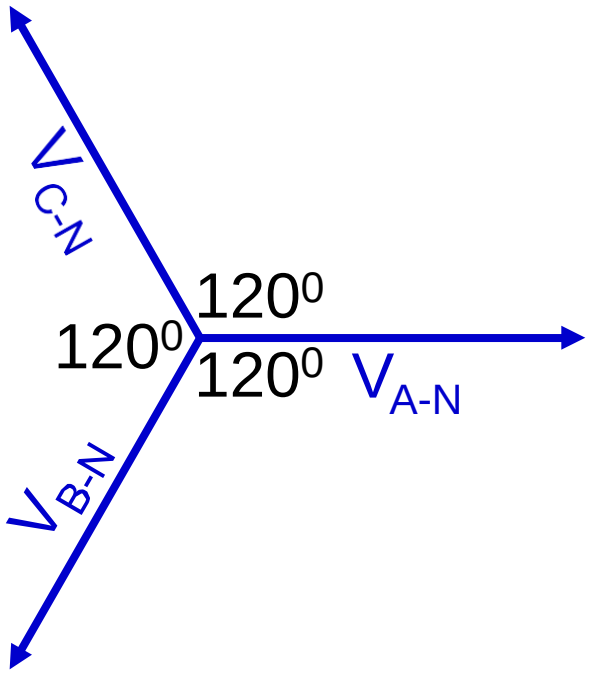
Arithmetically combined kVAh ≥ Vectorally combined kVAh

They are equal only if all phases have equal phase angles.

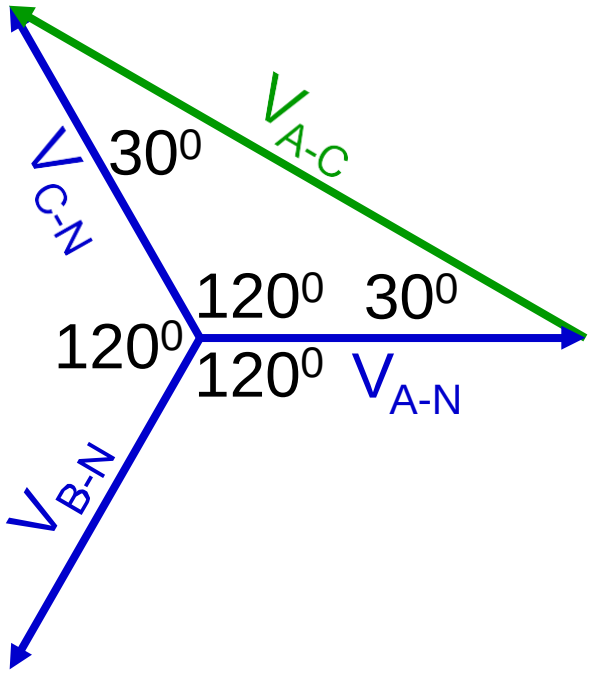
VOLTAGES IN A WYE-CONNECTION

$$V_{L\text{-}L} = \sqrt{3}\ V_{L\text{-}N}$$

We can prove this by constructing the Line-voltage (L-L) phasors based on the Phase-voltage (L-N) phasors.



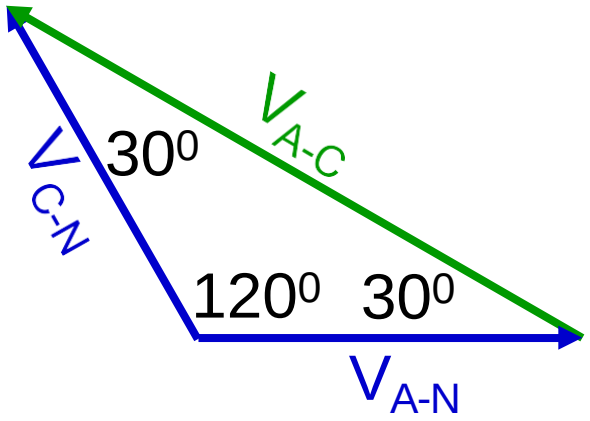
VOLTAGES IN A WYE-CONNECTION



VOLTAGES IN A WYE-CONNECTION

Using the Law of Sines:

$$\frac{V_{A\text{-}C}}{\text{sine } 120^0} = \frac{V_{A\text{-}N}}{\text{sine } 30^0}$$



$$V_{A\text{-}C} = V_{A\text{-}N} \text{ sine } 120^0 / \text{ sine } 30^0$$

$$V_{A\text{-}C} = \sqrt{3}\ V_{A\text{-}N}$$

Questions and Discussion

Tom Lawton

tom.lawton@tescometering.com

TESCO – The Eastern Specialty Company

Bristol, PA

215-228-0500

This presentation can also be found under Meter Conferences and Schools on the TESCO website: tescometering.com

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