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SARI / Energy

Measurement of Power in single and 3-Phase Circuits

by : N.K.Bhati

A specifically designed programme for

Da Afghanistan Breshna Sherkat (DABS)
Afghanistan

Areas Covered Under this Module

1. Power in ac circuits
2. Measurement of power and Energy in single and three circuits
3. Two and three wattmeter methods in balance and unbalance circuits

Power in ac circuits.. a quick recap

- Power per phase is

  $P = V_p I_p \cos(\phi)$

- Power for all three phases is

  $P = 3 V_p I_p \cos(\phi)$ or

  $P = V_1 I_1 \cos(\phi_1) + V_2 I_2 \cos(\phi_2) + V_3 I_3 \cos(\phi_3)$

- Since for a balanced load the power is constant

  $P(t) = 3 V_p I_p \cos(\phi)$ also

- Power in Terms of Line Quantities

  $P = \sqrt{3}\, V_L I_L \cos(\phi)$

Power in ac circuits.. a quick recap

- Total supply Volt Amps product (VA) is
  $VA = \sqrt{3}\, V_L\, I_L$
- Reactive power Q is the Quantity making up the difference between VA and Power

  $Q = \sqrt{3}\, V_L\, I_L \sin(\phi)$
- Thus $VA^2 = P^2 + Q^2$
- Q is a measure of the energy storage capability of the circuit
- For the greatest Power per amp of supply the Power Factor should be Unity and Q should be zero

Power in ac circuits.. a quick recap

- Balanced conditions
  - All 3 phase voltages (rms) are equal
  - All 3 phase currents (rms) are equal
  - Phase angle ϕ is the same for all 3 phases
  - 120 degrees electrical between voltages

- Balanced conditions give no neutral current
- Instantaneous Power is constant
- Reactive power Q when ϕ is not zero reduces utilisation of current

Measurement of Power and Energy

- *Power is the rate at which energy is transformed.*

- *Measurement of* active power *: by wattmeter*
  (an indicating type *Instrument)*
- *Measurement of* energy : *by Energy* meter
  (an integrating *type instrument)*

Wattmeter

- Electro-dynamic or Dynamometer type.
- Induction type or Electromechanical meter
- Thermal type
- Electronic instruments

Electrodynamic wattmeter

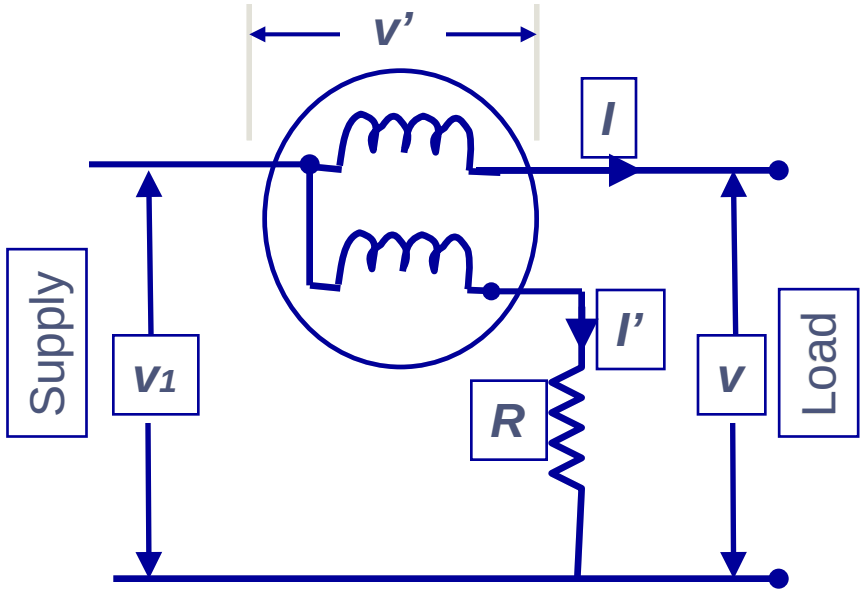
- The device consists of a pair of fixed coils, known as *current coils*, and a movable coil known as the *potential coil*.
- The current coils connected in series with the circuit, while the potential coil is connected in parallel.
- On analog wattmeters, the potential coil carries a needle that moves over a scale to indicate the measurement.
- A current flowing through the current coil generates an electromagnetic field around the coil. The strength of this field is proportional to the line current and in phase with it.
- On an ac circuit the deflection is proportional to the average instantaneous product of voltage and current, thus measuring true power (P= v.i)

Digital watt meters

- Based on Analog or dig
  techniques of
  measurement.
- Measures true rms V,I
  Watts.
- Low cost , high accurac

Measurement of Power in Single Phase AC Circuits

– Single wattmeter method



Three or Two Wattmeter Method

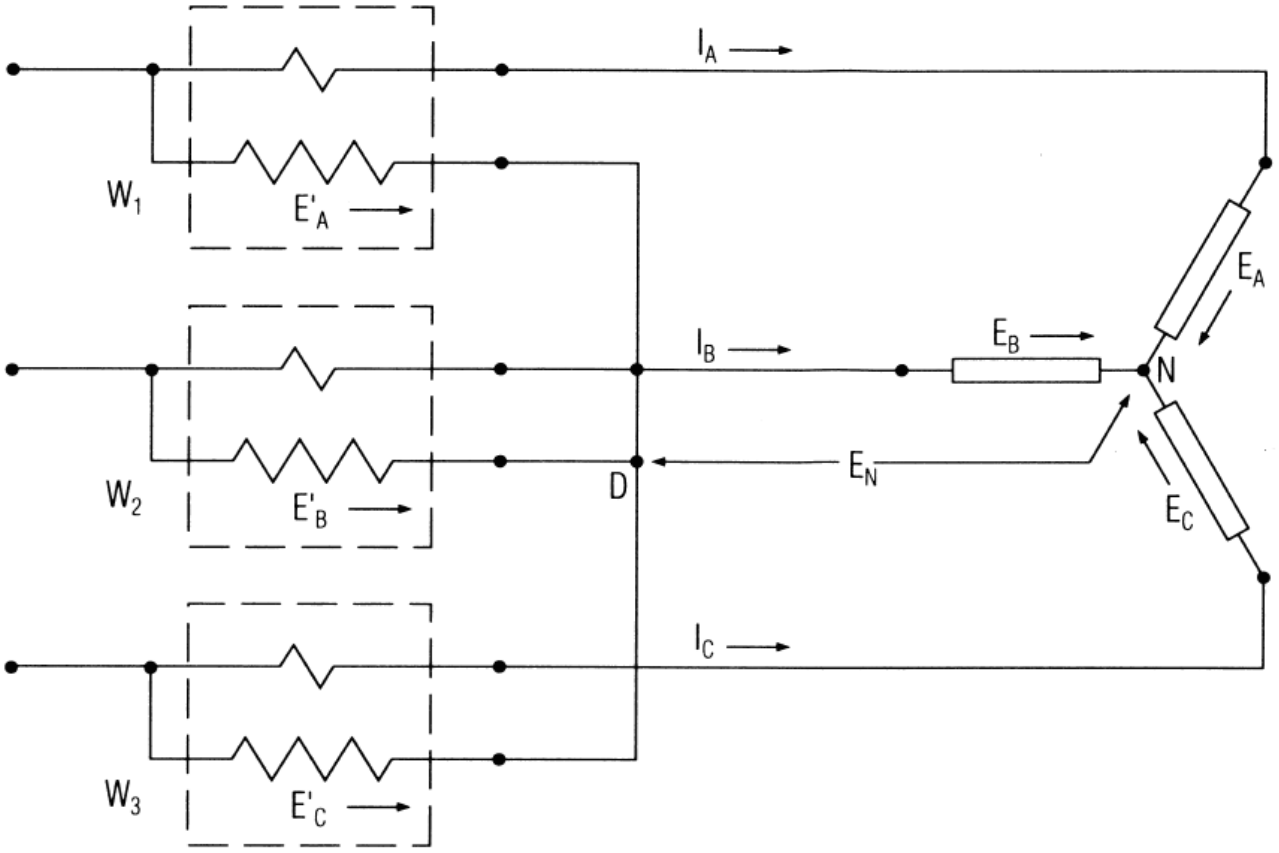
- BLONDEL'S THEOREM
  - In an N-wire circuit, only (N-1) watt meters are required to measure the power.

- 2 Wattmeter method measures the power of 3 phase star or delta connected balanced / unbalanced loads
- 3 wattmeter method is used for 4 wire circuits , like LT or HT circuits

Measurement of Power in 3 Phase Circuits

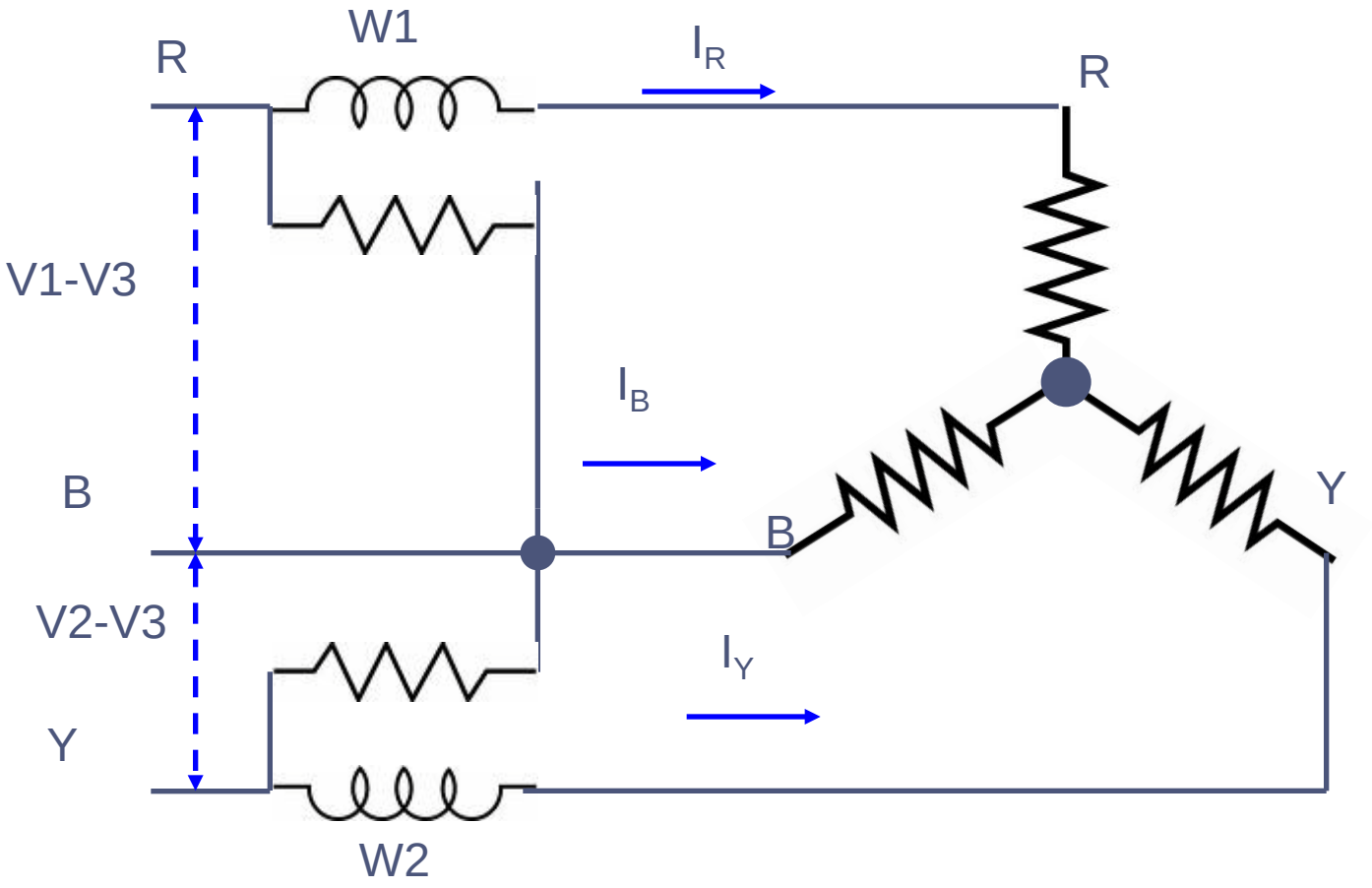
- 3-Wattmeter Method
  - The method is applicable in 3-phase 4 wire circuits, Works well for balanced and unbalanced loads.
  - In 3phase 3 wire circuits an artificial neutral is created through 3 equal high resistances connected in star.
  - In case of low voltage circuits three potential coils may be connected to form a common star.

3 phase power Measurement : 3 Wattmeter Method



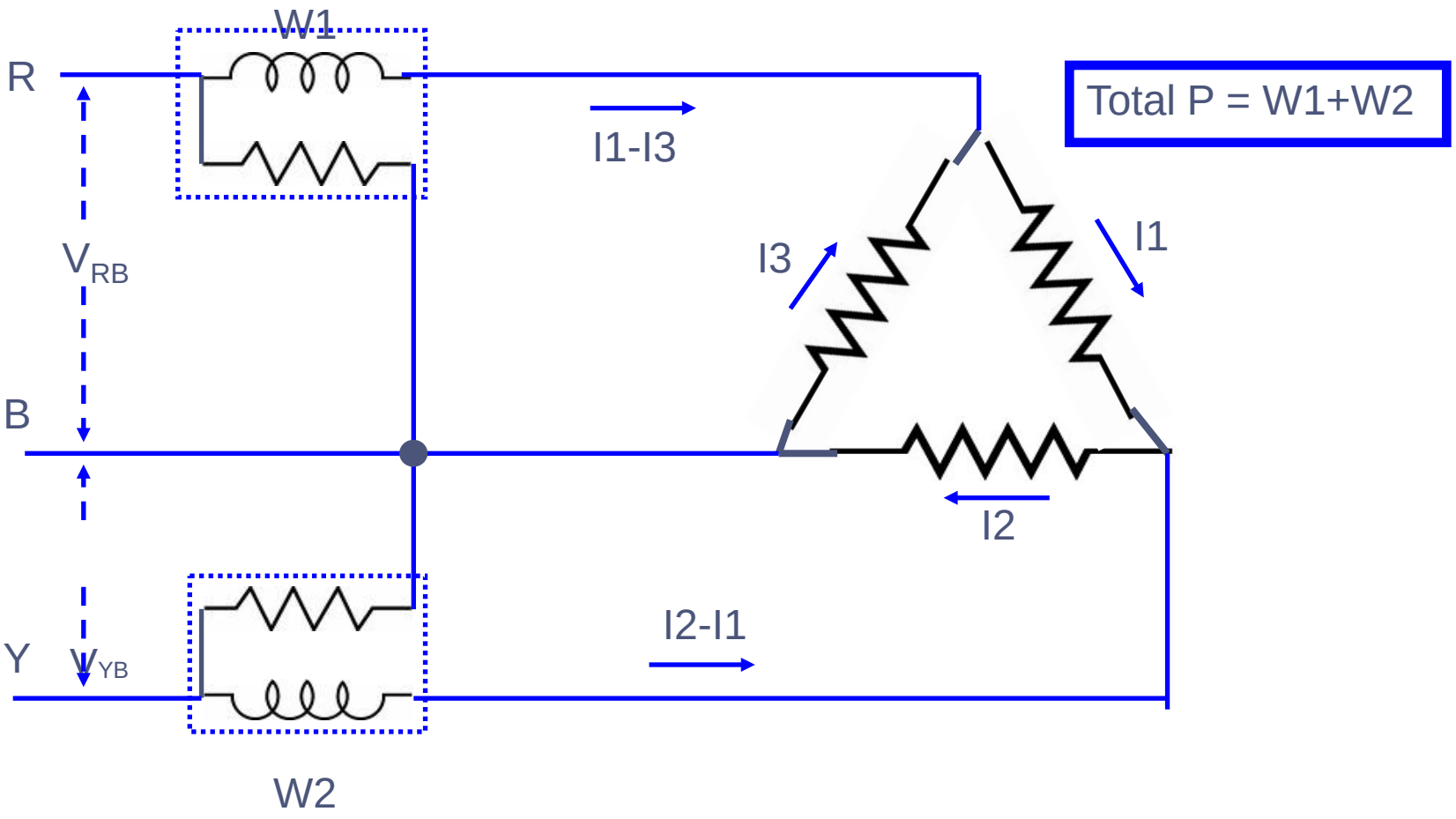
Total power of load circuit, P = W1 + W2 + W3

Two Wattmeter Method in Star Circuit



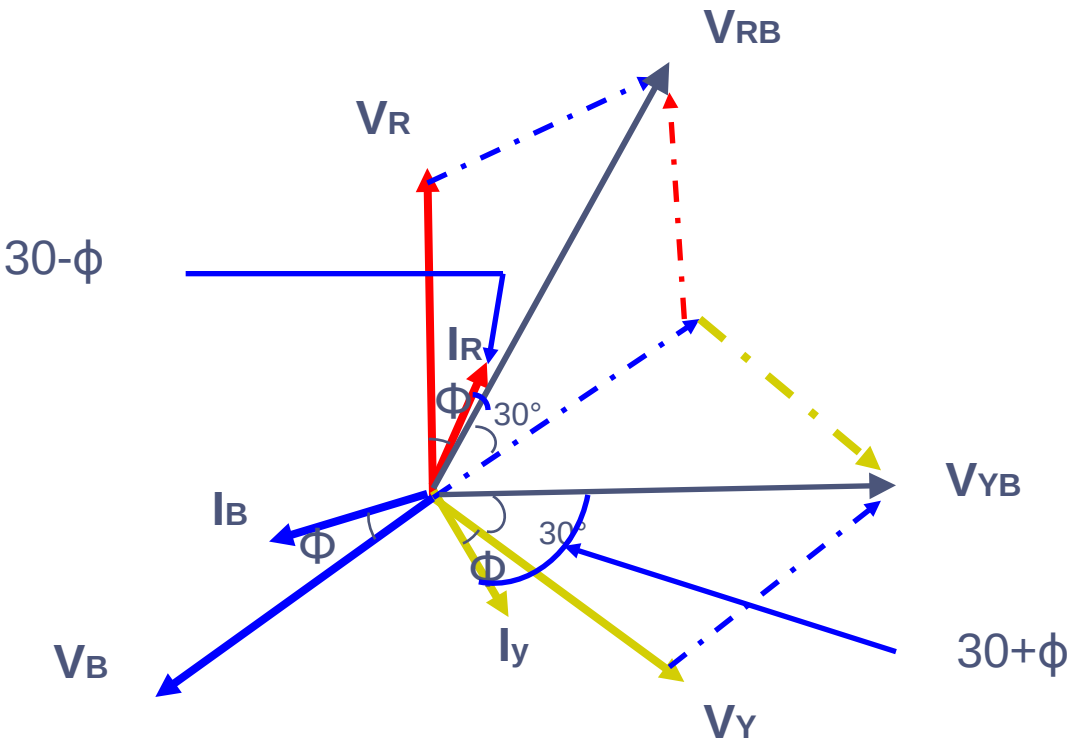
Total average power P = W1+ W2

Two wattmeter in Delta circuit



3 Φ 3 W Method

Vector Representation



3 Φ 3 W Method

Total Power = sum of two watt meter readings

W1 + W2

= Vrb.Ir. cos (30°- Φ) + Vyb.Iy. cos (30°+ Φ)

= $V_L I_L \times 2 \cos 30° \cos\Phi$

= $\sqrt{3}\, V_L I_L \cos \Phi$

= 3VI cos Φ

= True power of load

(This is true for any phase used as reference, as well for unbalanced loads also.)

Measurement of energy

- Power integrated over time gives energy
- All energy meters do this.
  - In EM induction type meters, speed of rotation of the disk is proportional to power, and integrated by use of gear trains and mechanical counters.
  - In electronic (analog type meters), power is converted to a proportional frequency or pulse rate , and integrated by use of EM counters.
  - In Digital Energy meters, power is continuously integrated in digital domain by processor to get energy and is also converted to a proportional frequency or pulse rate for calibration /testing purpose.

Connections

- Classification of Energy Meters
- Connection of 3-Ø, Whole Current Meter
- Connection of 3-Ø, LT-CT Operated Meter
- Connection of HT, 3P4W Meter
- Connection of HT, 3P3W Meter
- Connection of Single phase 2E Meter
- Precautions while connecting Meters
- Connection check for 3P4W and 3P3W Meters

Classification of Energy Meters

Metering Point

Network Section	HV/LV	3/4 wire
Grid	HV 275/400kV	3 wire
Secondary Trans. Primary Dist.	HV 33/11kV	3 wire
Local Dist.	LV 400V 400V 230V (1∅)	 3 wire 4 wire 2 wire

HV = High Voltage, LV = Low Voltage

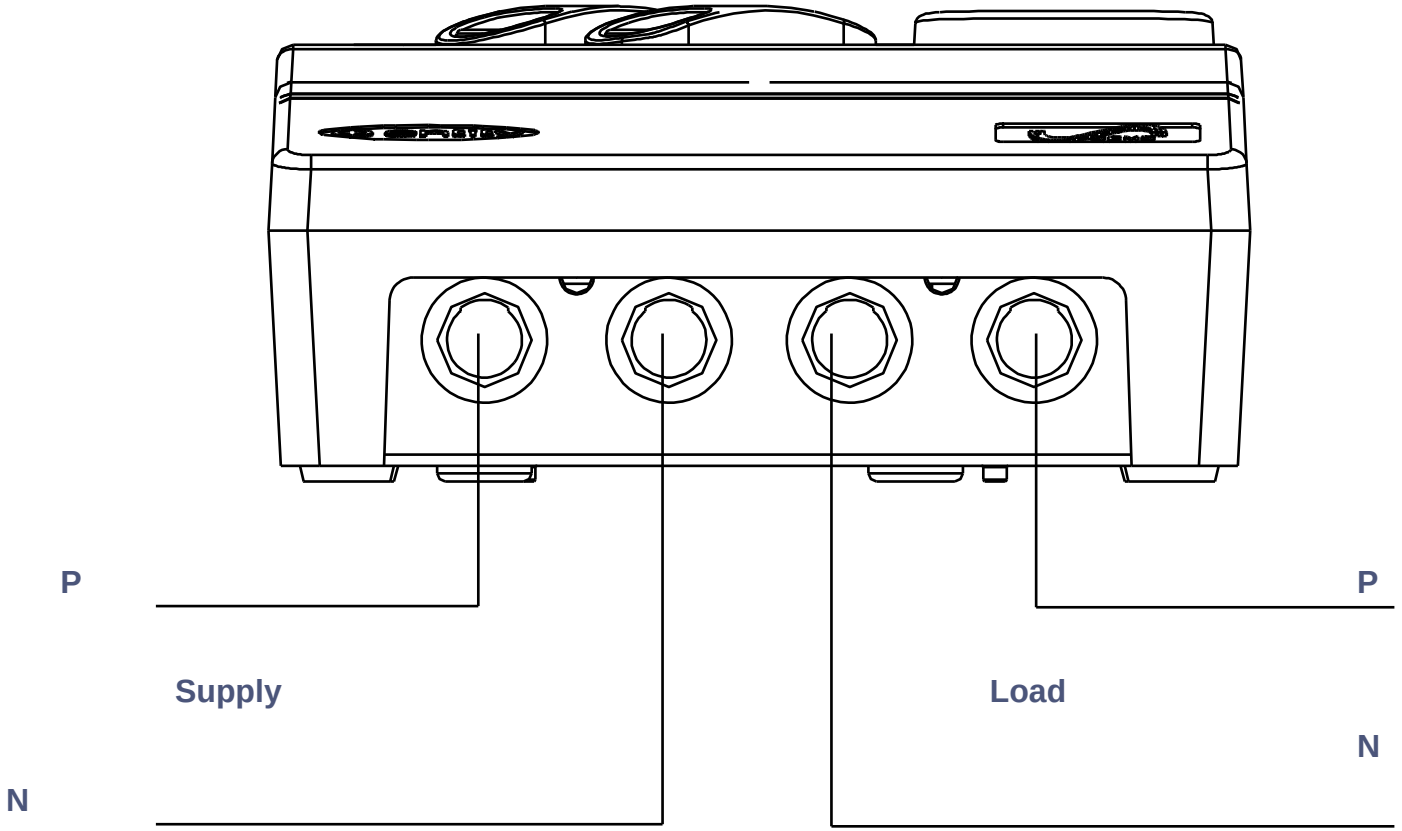
End Application

- Domestic
- Commercial
- Industrial (Small, Medium, Large)
- Grid Metering
- Billing or Check Meter
- Nature of Load (Traction, Induction furnace)

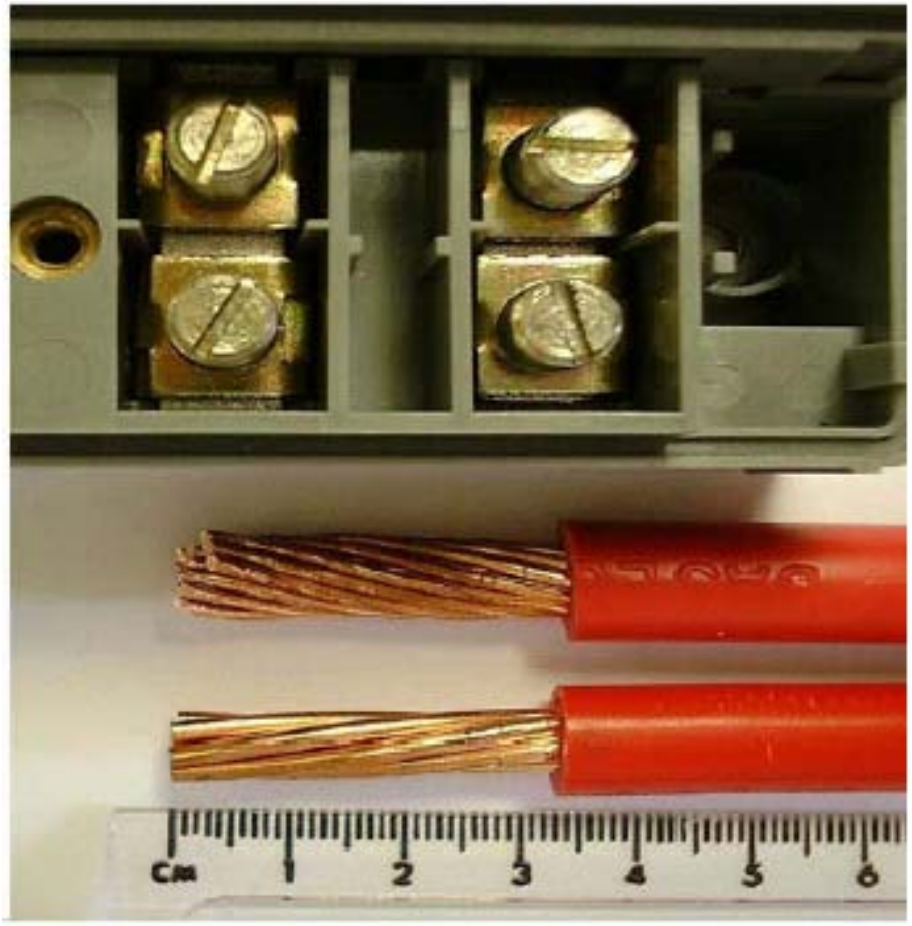
Technical

- Three phase or Single phase
- HT, LT or Whole Current
- If HT then 3P4W or 3P3W
- Basic Voltage (Vb)
- Basic Current (Ib)
- Max Current (Imax) for long rage meter
- Accuracy class (0.2s, 0.5s, 1.0, 2.0)

Single Phase Meter Connection



Precautions while Connecting Meter

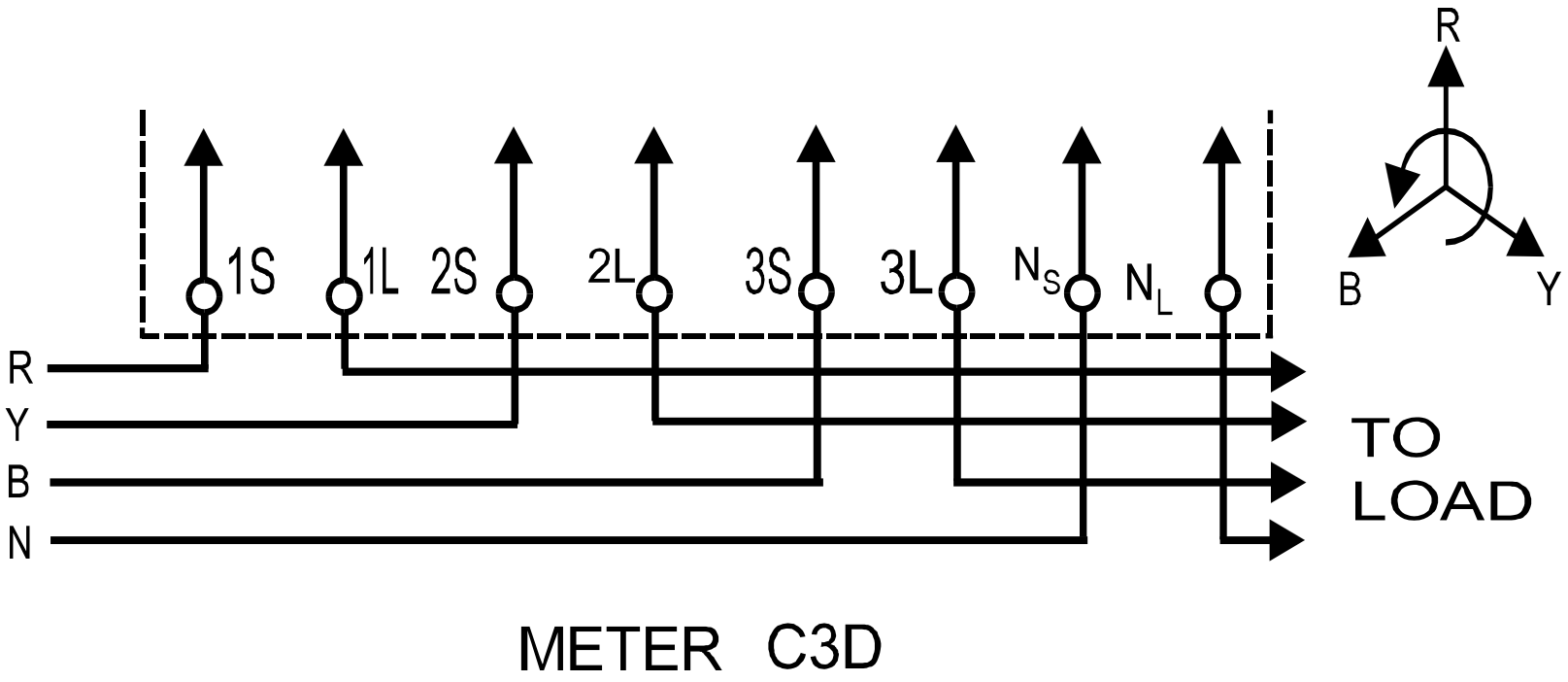


- Use cable size as per the current rating
- Remove insulation exactly equal to terminal depth.

13mm Diameter Cable

11mm Diameter Cable

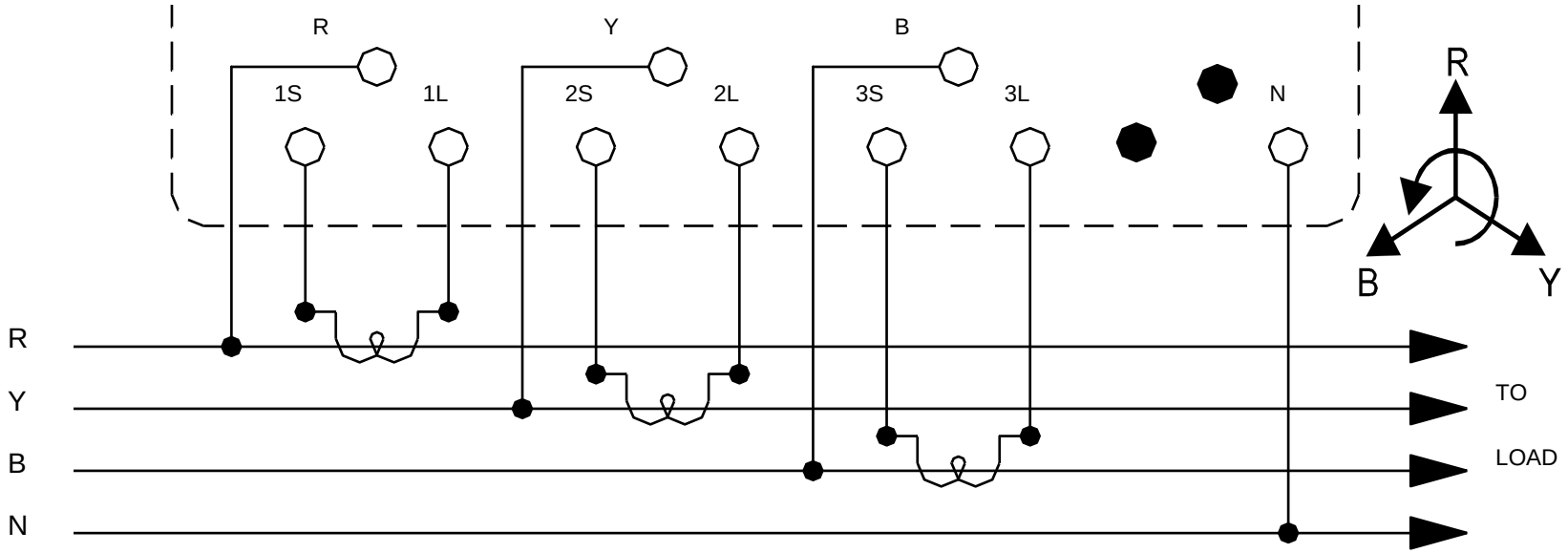
Whole Current Meter



LT-CT 3P4W Meter

CT secondary rating: 1A or 5A

CT Primary rating: can be commissioned to any one of the standard values

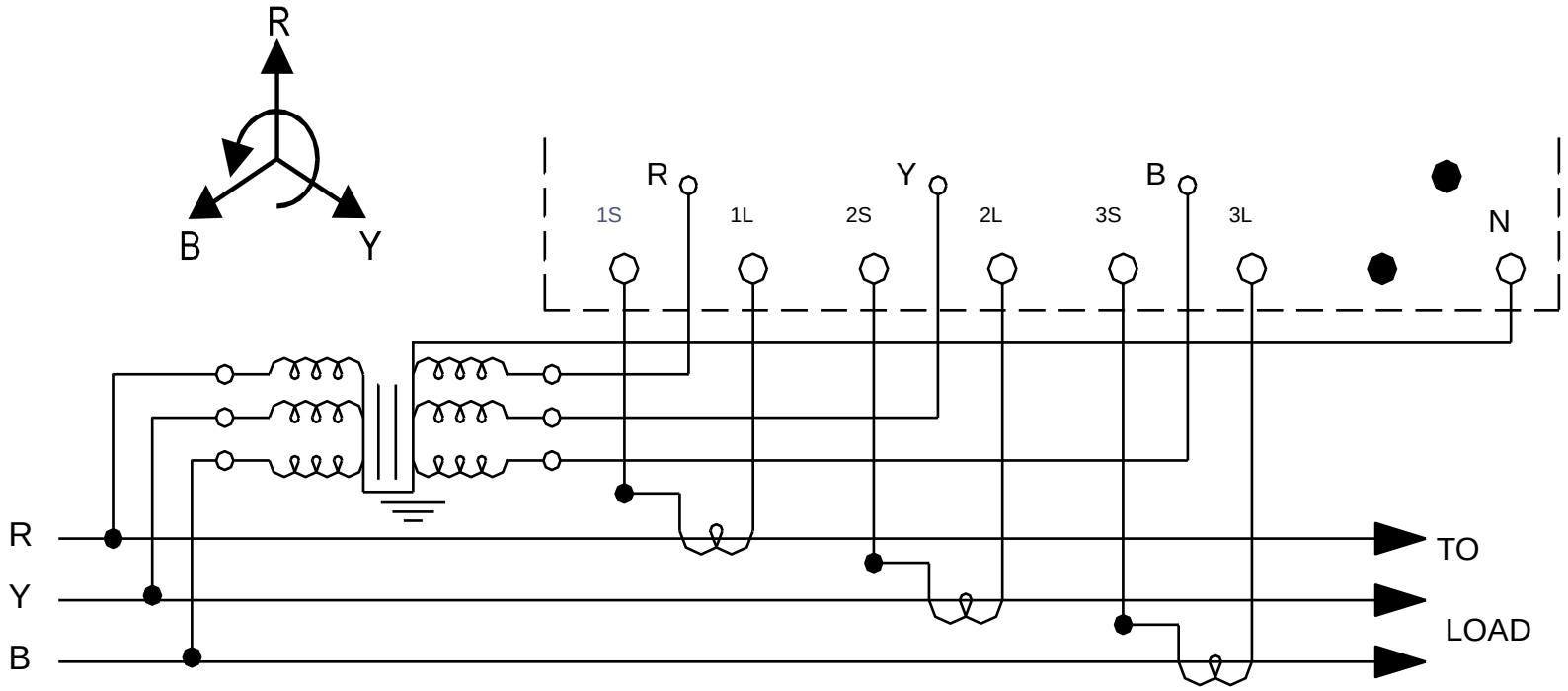


C3T Type Meter

HT 3P4W Meter

Voltage rating: 110/ √ 3 V, Sec. current rating: 1A or 5A

Primary voltage and current range can be commissioned to any one of standard values.

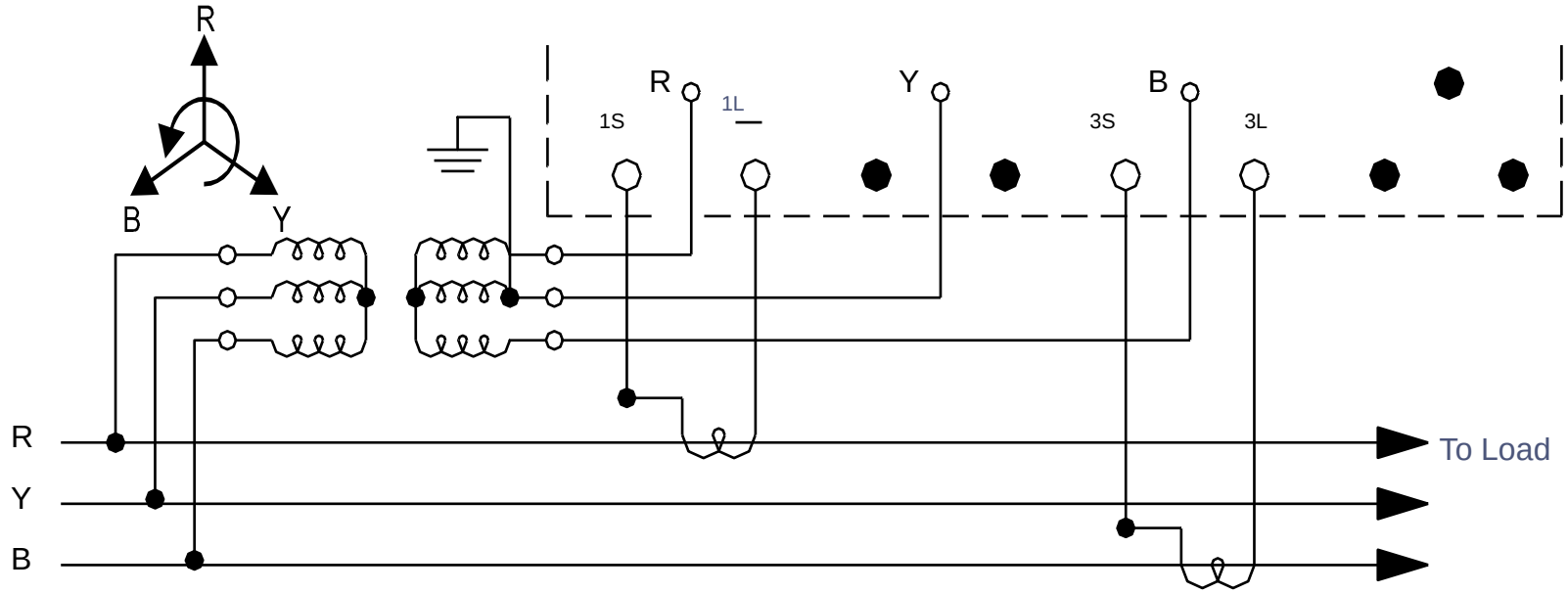


C3M Type Meter

HT 3P3W Meter

Voltage rating: 110V, Sec. Current rating:1A or 5A

Primary voltage and current range can be commissioned to any one of standard values.

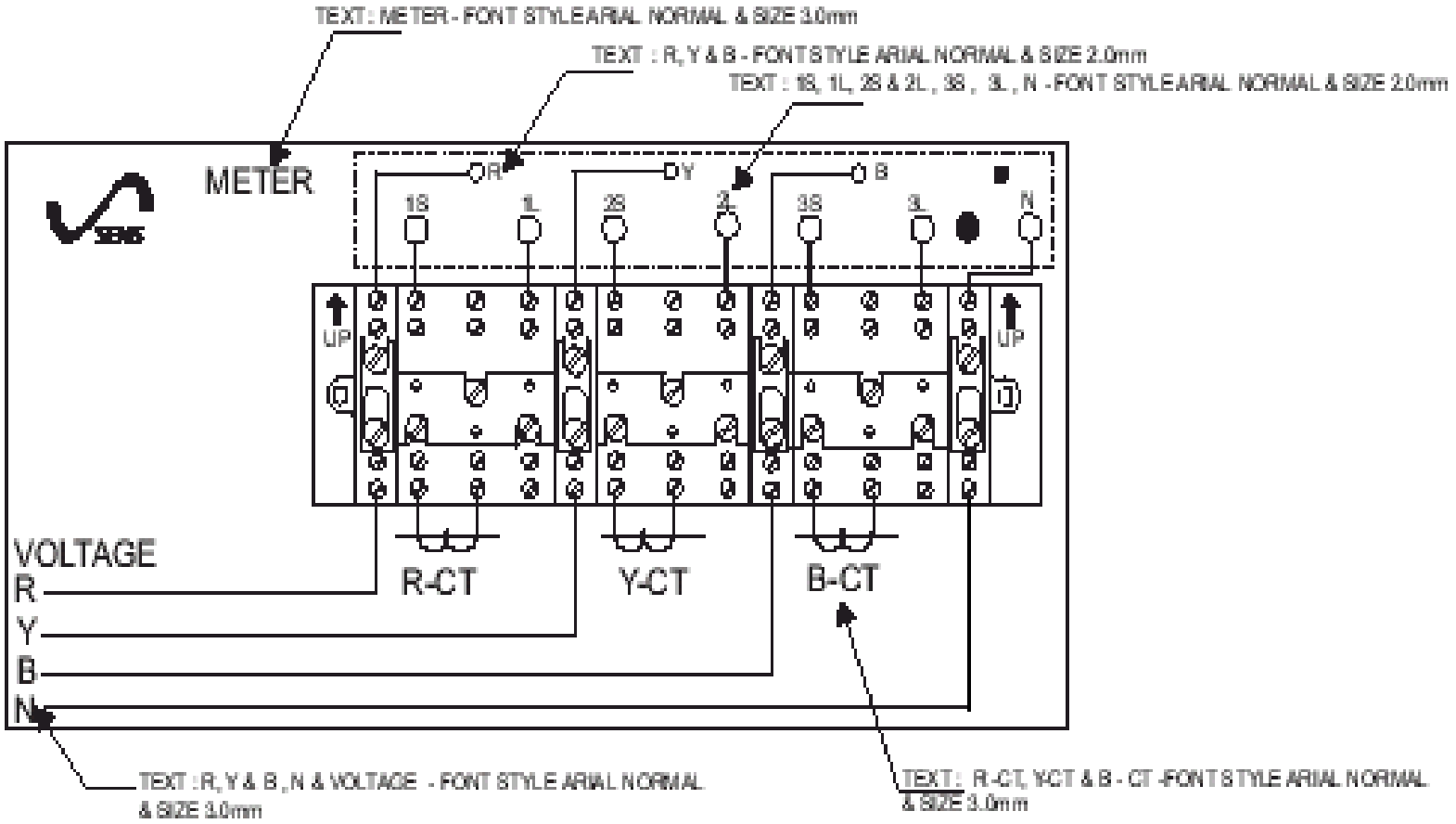


C3V Type Meter

Precautions while Connecting CT-Operated Meter

- Meter must be connected using Test Terminal Block (TTB)
- CT Secondary must kept shorted until meter is connected.
- Under no case CT secondary shall be open, it may result in high voltage flash over or CT burst.

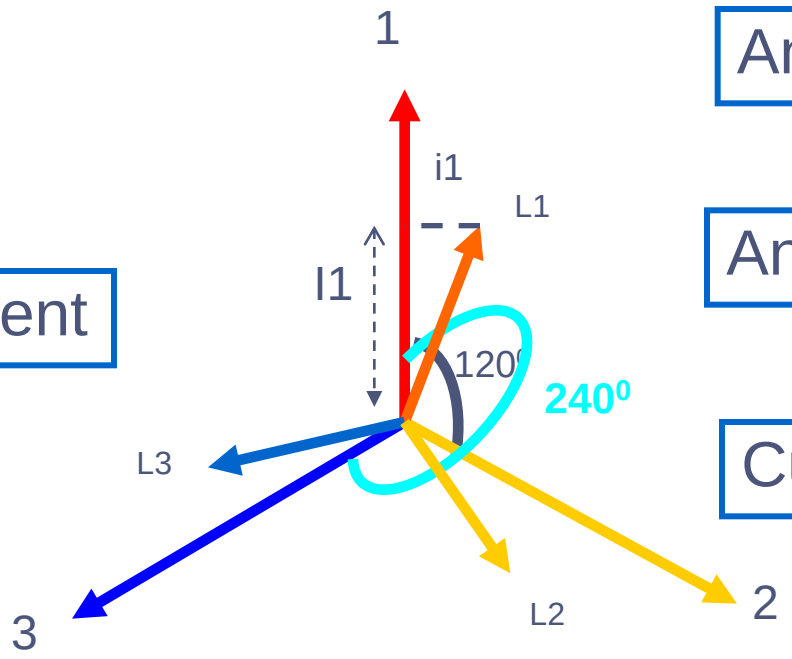
TTB



PRINTING DETAILS

Meter Connection Check

Vector diagram 3P4W – Connection Check



Angle between R&Y

Angle between R&B

Active Current

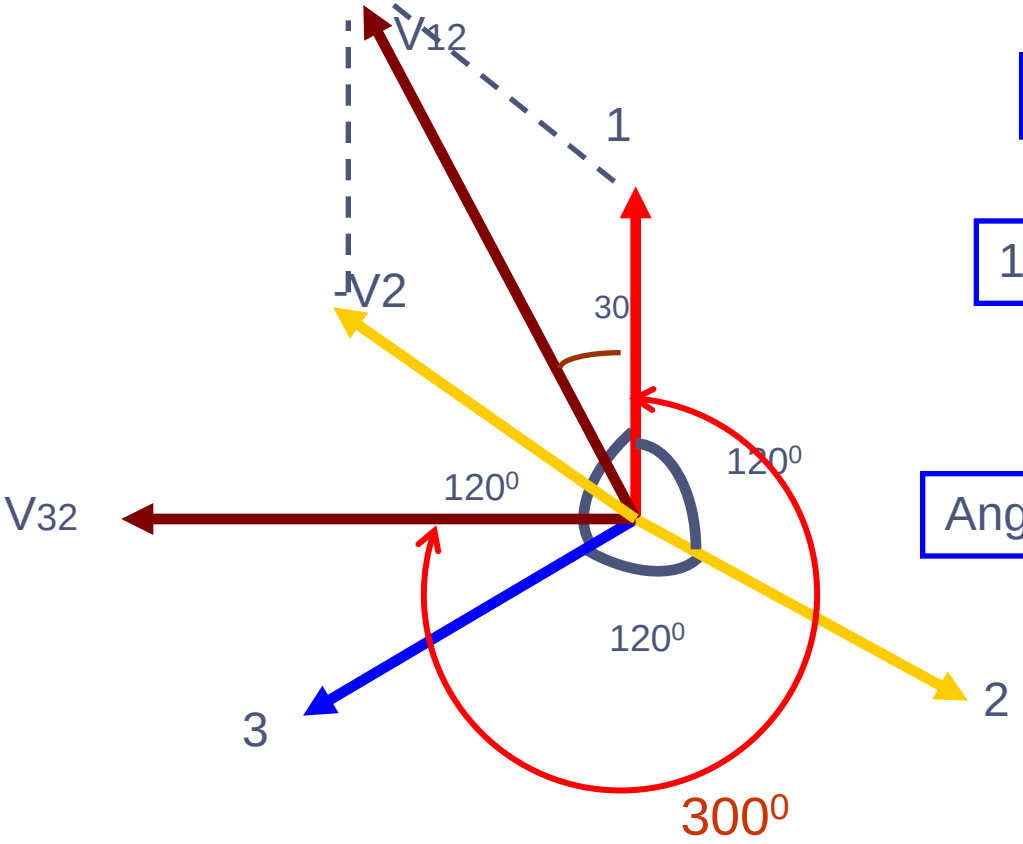
Current Phasors

Reactive Current

Connection Check for 3P4W Meter

- Read V1, V2, V3, L1, L2, L3, I1, I2, I3 , A2, A3 from the meter
- Draw the vector diagram as shown. The phase sequence is find out by reading angle A2 and A3 which have value 120° & 240° respectively for RYB (forward phase sequence) and 240° & 120° for RBY (reverse phase sequence).

3P3W Meter – Connection check



1,2,3 phase voltages

12,23,31 – Line voltages

Angle Between V12 and V32

Connection Check for 3P3W Meter

- Read V1, V3, L1, L3, I1, I3, i1, i3 etc.
- Draw the vector diagram as shown.
- The phase sequence is find out by reading angle A3 which will have value 300° for RYB (forward phase sequence) and 60° for RBY (reverse phase sequence).

Question Please?

Thank you