

Lecture 8

Electrical Measurement and
Instrumentation

Power-factor Meters

- The power factor, by definition, is the cosine of the phase angle between voltage and current
 - power-factor measurements usually involve the determination of this phase angle.
- This is demonstrated in the operation of the crossed-coil power-factor meter.
- Basically an electro-dynamometer movement consists of two coils, mounted on the same shaft but at right angles to each other.
- The moving coils rotate in the magnetic field provided by the field coil that carries the line current.

Past Lecture

- Electrodynamometer in Power Measurement
- Wattmeter
- Compensation coils in Wattmeter
- Kilowatthour meter

Power-factor Meters

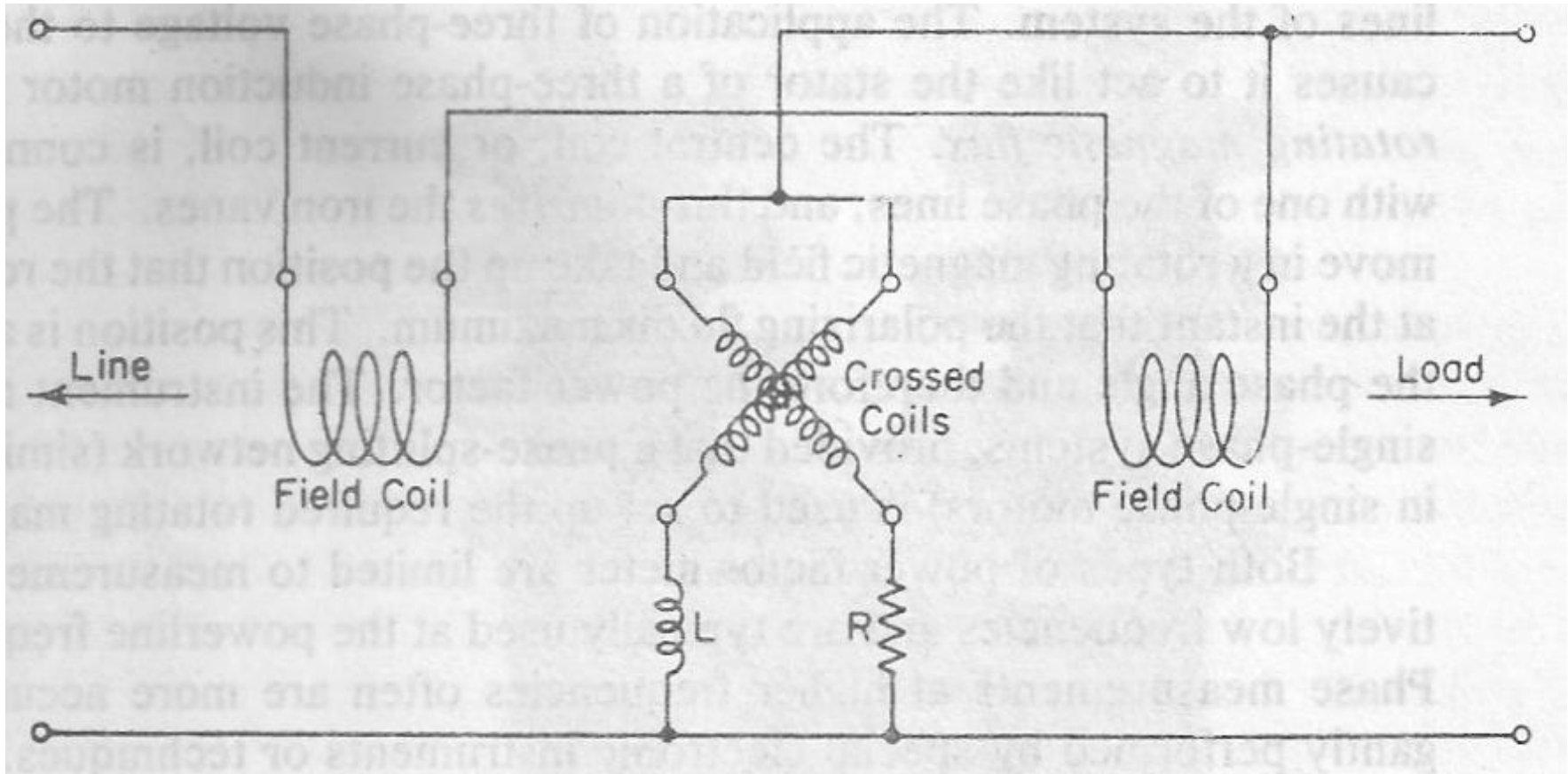


Figure 4-40 Connections for a single-phase crossed-coil power-factor meter.

Power-factor Meters

- The field coil is connected as usual in series with the line and carries the line current.
- One coil of the movable element is connected in series with a resistor across the lines and receives its current from the applied potential difference.
- The second coil of the movable element is connected in series with an inductor across the lines.
- Since no control springs are used, the balance position of the movable element depends on the resulting torque developed by the two crossed coils.

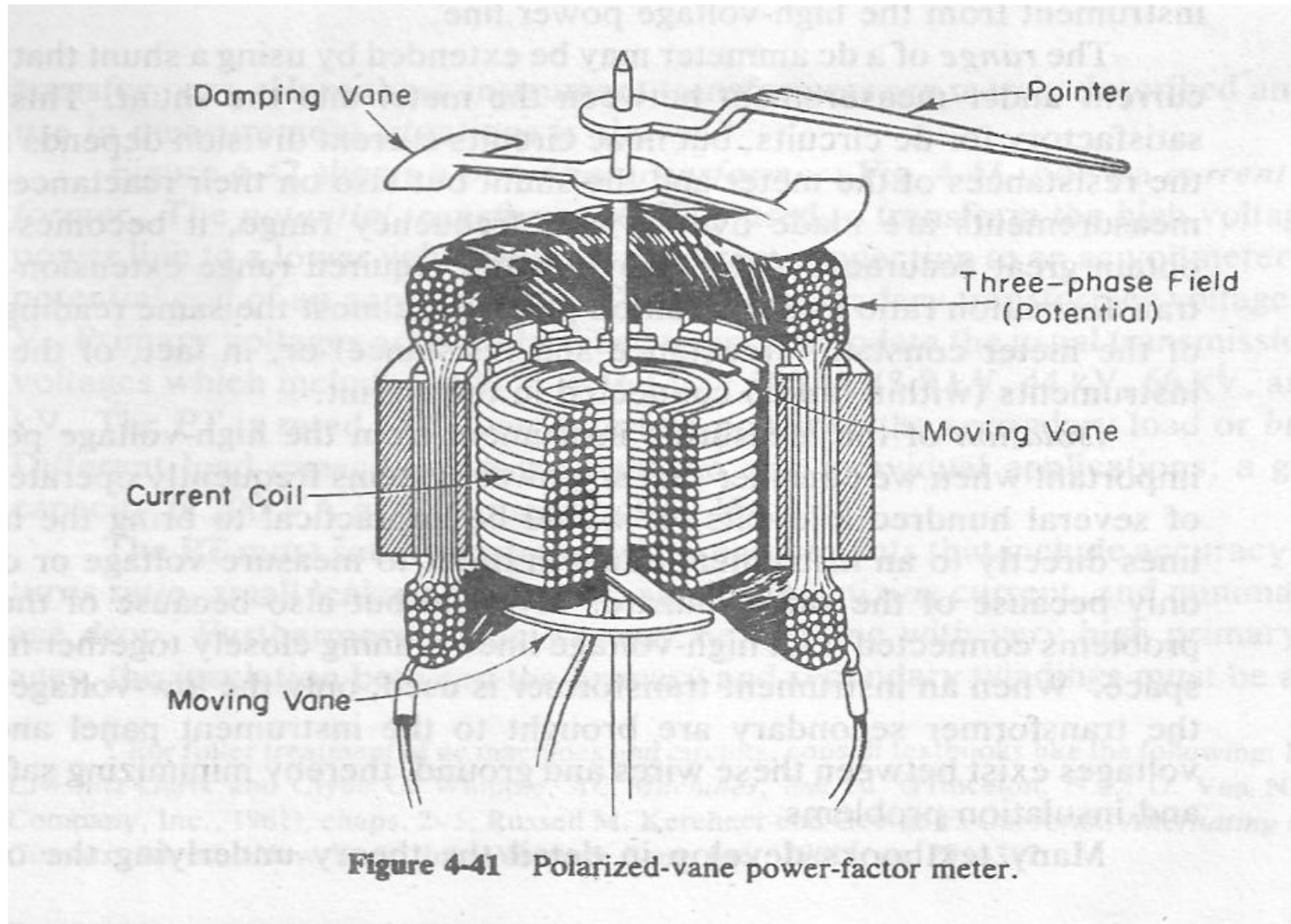
Power-factor Meters

- When the movable element is in a balanced position, the contribution to the total torque by each element must be equal but of opposite sign.
- The developed torque in each coil is a function of the current through the coil and therefore depends on the impedance of that coil circuit.
- The torque is also proportional to the mutual inductance between each part of the crossed coil and the stationary field coil.
- This mutual inductance depends on the angular position of the crossed-coil elements with respect to the position of the stationary field coil.

Power-factor Meters

- When the movable element is at balance, it can be shown that its angular displacement is a function of the phase angle between line current (field coil) and line voltage (crossed coils).
- The indication of the pointer, which is connected to the movable element, is calibrated directly in terms of the phase angle or power factor.
- The polarized-vane power-factor meter is shown in the construction sketch of Figure.
- This instrument is used primarily in three-phase power systems, because its operating principle depends on the application of three-phase voltage.

Power-factor Meters



Power-factor Meters

- The outside coil is the potential coil, which is connected to the three phase lines of the system.
- The application of three-phase voltage to the potential coil causes it to act like the stator of a three-phase induction motor in setting up a rotating magnetic flux.
- The central coil, or current coil, is connected in series with one of the phase lines, and this polarizes the iron vanes.
- The polarized vanes move in a rotating magnetic field and take up the position that the rotating field has at the instant that the polarizing flux is maximum.

Power-factor Meters

- This position is an indication of the phase angle and therefore the power factor.
- The instrument may be used in single-phase systems, provided that a phase-splitting network (similar to that used in single-phase motors) is used to set up the required rotating magnetic field.
- Both types of power-factor meter are limited to measurement at comparatively low frequencies and are typically used at the powerline frequency (60 Hz).
- Phase measurements at higher frequencies often are more accurately and elegantly performed by special electronic instruments or techniques.

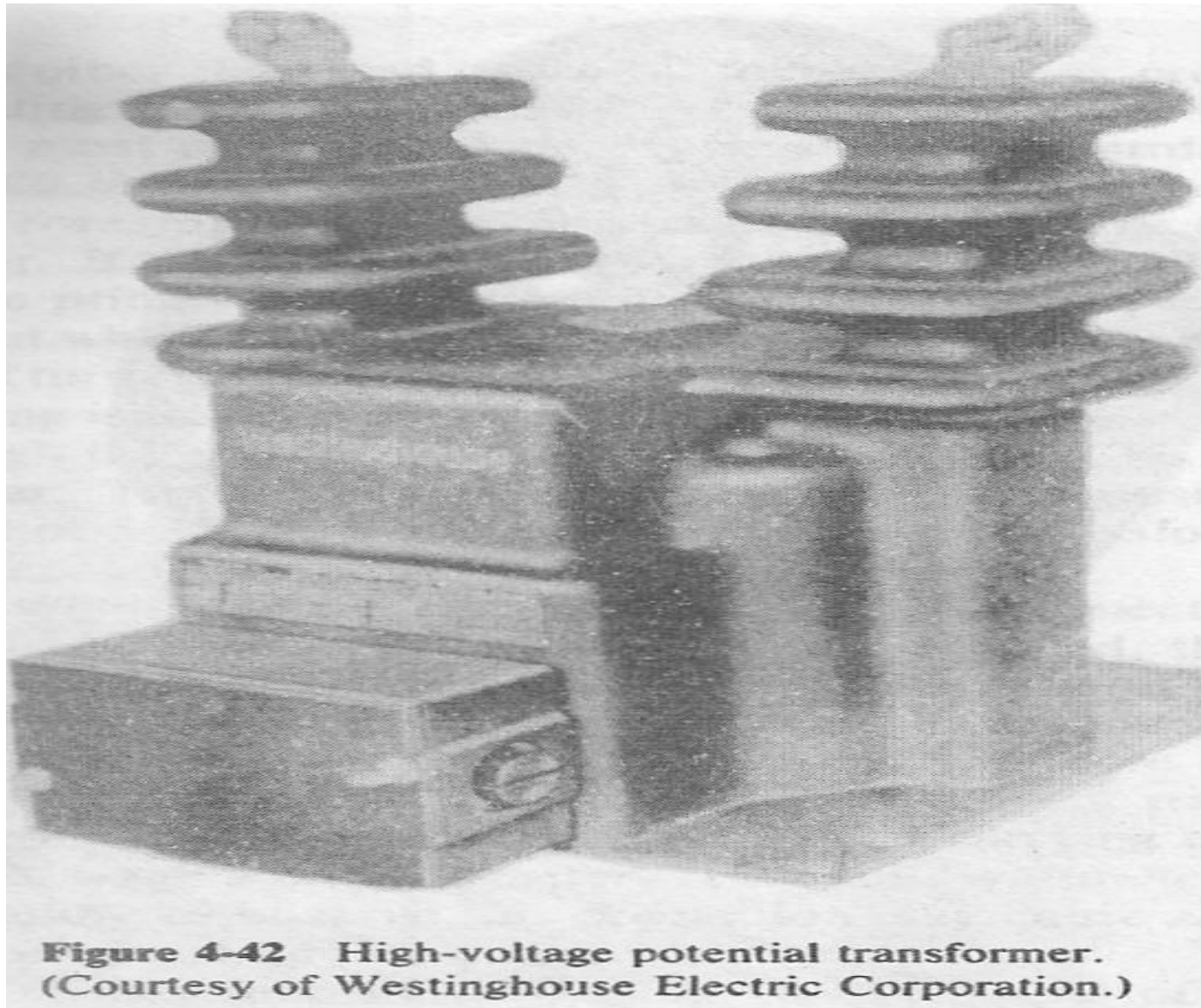
Instrument Transformers

- Instrument transformers are used to measure ac at
 - generating stations,
 - transformer stations, and
 - at transmission lines, in conjunction with ac measuring instruments (voltmeters, ammeters, wattmeters, VARmeters, etc.).
- Instrument transformers are classified according to their use and are referred to as
- Current transformers (CT) and
- Potential transformers (PT).

Instrument Transformers

- Instrument transformers perform two important functions:
 - They serve to extend the range of the ac measuring instrument, much as the shunt or the multiplier extends the range of a dc meter
 - they also serve to isolate the measuring instrument from the high-voltage power line.
- The range of a dc ammeter may be extended by using a shunt that divides the current under measurement between the meter and the shunt.
- Since ac measurements are made over a wide **frequency** range, it becomes difficult to obtain great accuracy.
- CT provides the required range extension through its **transformation ratio** and in addition produces almost the same reading regardless of the meter constants (reactance and resistance) or, in fact, of the number of instruments (within limits) connected in the circuit.

Instrument Transformers



Instrument Transformers



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Figure 4-43 Current transformer.
(Courtesy of Westinghouse Electric
Corporation.)

Instrument Transformers

- Isolation of the measuring instrument from the high-voltage power line is important when we consider that ac power systems frequently operate at voltages of several hundred kilovolts.
- It would be impractical to bring the high-voltage lines directly to an instrument panel in order to measure voltage or current, not only because of
 - the safety hazards involved but also because of
 - the insulation problems connected with high-voltage lines running closely together in a confined space.

So.....

When an instrument transformer is used, only the low-voltage wires from the transformer secondary are brought to the instrument panel and only low voltages exist between these wires and ground, thereby minimizing safety hazards and insulation problems

Instrument Transformers (PT)

- The potential transformer (PT) is used to transform the high voltage of a power line to a lower value suitable for direct connection to an ac voltmeter or the potential coil of an ac wattmeter.
- The usual secondary transformer voltage is 120 V.
- Primary voltages are standardized to accommodate the usual transmission line voltages which include 2,400 V, 4,160 V, 7,200 V, 13.8 kV, 44kv, 66kv, and 220 kV.
- Different load capacities are available to suit individual applications;
 - a general capacity is 200 VA at a frequency of 60 Hz.

Instrument Transformers

- The PT must satisfy certain design requirements that include
 - accuracy of the turns ratio,
 - small leakage reactance,
 - small magnetizing current, and
 - minimal voltage drop
- In the usual case, the core and coil assembly is then mounted inside a steel case, which supports the high-voltage terminals or porcelain bushings.
 - The case is then filled with an insulating oil.

Instrument Transformers

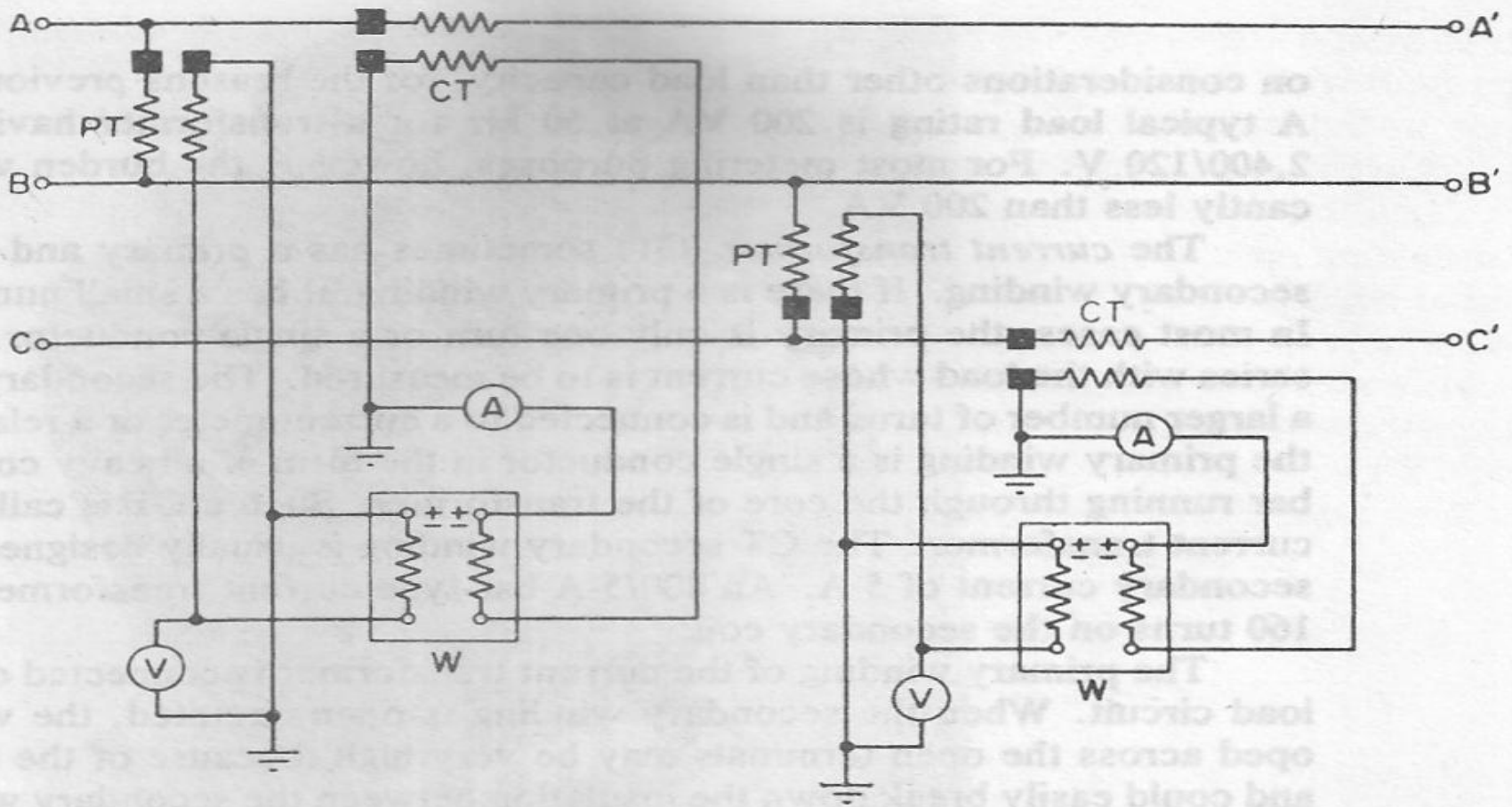


Figure 4-44 Instrument transformers in a three-phase measurement application. Polarity markings of the potential and current transformers are indicated by black squares.

Instrument Transformers

- This diagram illustrates the connection of instrument transformers in a three-wire-three-phase circuit, including two wattmeters, two voltmeters, and two ammeters.
- The potential transformers are connected across phase lines A and B, and phase lines C and B; the current transformers are in phase lines A and D.
- The secondary windings of the potential transformers are connected to the voltmeter coils and the potential coils of the wattmeters;
 - the current transformer secondary windings feed the ammeters and the current coil of the wattmeters.
- The polarity markings on the transformers, indicated by a dot at the transformer leads, aid in making the correct polarity connections to the measuring instruments.
- At any given instant of the ac cycle, the dot-marked terminals have the same polarity and the marked wattmeter terminals must be connected to these transformer leads as shown.