Lecture 7

Electrical Measurement and Instrumentation

Electrodynamometers in Power Measurements

- The electrodynamometer movement is used extensively in measuring *power*.
- Indicates both dc and ac power for any waveform of voltage and current
  - it is not restricted to sinusoidal waveforms.
- The fixed coils, or field coils, shown here as two separate elements, are connected in series and carry the total line current (i_c).
- The movable coil, located in the magnetic field of the fixed coils, is connected in series with a current- limiting resistor across the power line and carries a small current (i_p).
- The instantaneous value of the current in the movable coil is

$$i_p = e/R_p$$

where **e** is the instantaneous voltage across the power line, and $\mathbf{R_p}$ is the total resistance of the movable coil and its series resistor.

Electrodynamometers in power measurements

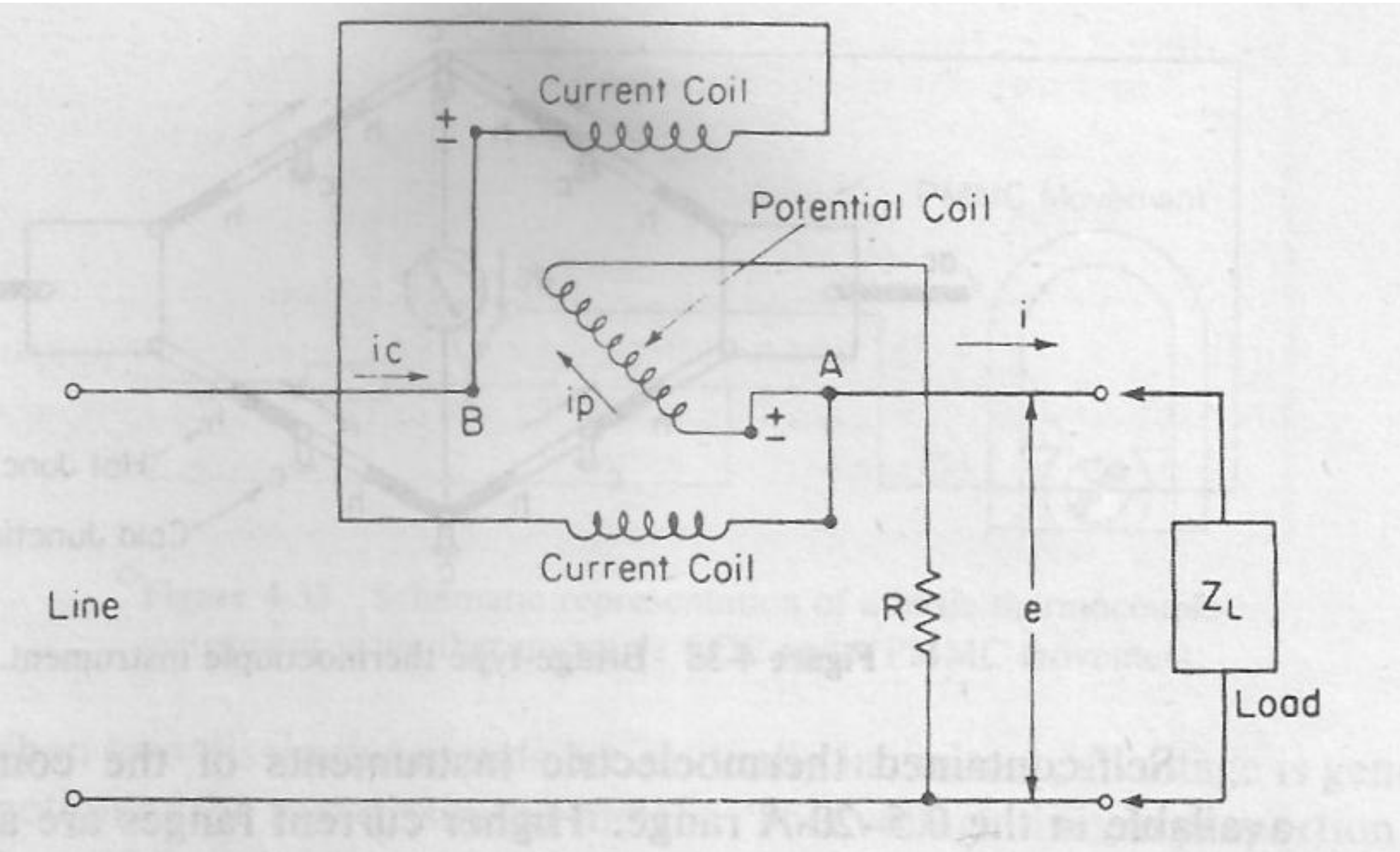

Figure 4-36 Diagram of an electrodynamometer wattmeter connected to measure the power of a single-phase load.

Electrodynamometers In Power Measurements

- The deflection of the movable coil is proportional to the product of these two currents, i_c and i_p, and we can write for the average deflection over one period:
- $$\theta_{av} = K\frac{1}{T}\int_0^T i_c i_p dt \qquad (4\text{-}28)$$
- where θ_{av} = average angular deflection of the coil
- K = instrument constant
- i_c = instantaneous current in the field coils
- i_p = instantaneous current in the potential coil
- Assuming for the moment that i_c is equal to the load current, i (actually, $i_c = i_p + i$), and using the value for $i_p = e/R_p$, we see that Eq. (4-28) reduces to
- $$\theta_{av} = K\frac{1}{T}\int_0^T i\frac{e}{R_p}dt = K_2\frac{1}{T}\int_0^T ei\ dt \qquad (4\text{-}29)$$

Electrodynamometers In Power Measurements

- By definition, the avenge power in a circuit is
- $$P_{av} = \frac{1}{T}\int_0^T ei\, dt \qquad (4\text{-}30)$$
- which indicates that the electrodynamometer movement, connected in the configuration shown in Fig, has a deflection proportional to the average power.
- If ***e*** and ***i*** are sinusoidally varying quantities of the form $e = E_m \sin wt$ and $i = I_m \sin(wt \pm \theta)$, Eq. (4-29) reduces to

$$\theta_{av} = K_3 EI \cos\theta \qquad (4\text{-}31)$$

- where **E** and **I** represent the rms values of the voltage and the current, and **θ** represents the phase angle between voltage and current.
- Wattmeters have one voltage terminal and one current terminal marked "±."
- When the marked current terminal is connected to the incoming line, and the marked voltage terminal is connected to the line side in which the current coil is connected, the meter will always read up-scale when power is connected to the load.

Electrodynamometers In Power Measurements

- The electrodynamometer wattmeter consumes some power for maintenance of its magnetic field.
- For a correct reading of the load power, the current coil should carry exactly the load current, and the potential coil should be connected across the load terminals.
- With the potential coil connected to point A, as in *Fig. 4-36*, the load voltage is properly metered, but the current through the field coils is greater by the amount i_p

Electrodynamometers connections for Power Measurements

- Choice of the correct connection depends on the situation.
- Generally, connection of the potential coil at point A is preferred for high-current, low-voltage loads; connection at B is preferred for low current, high-voltage loads.
- The difficulty in placing the connection of the potential coil is overcome in the compensated wattmeter, shown in the following Figure.

Electrodynamometers in Power Measurements

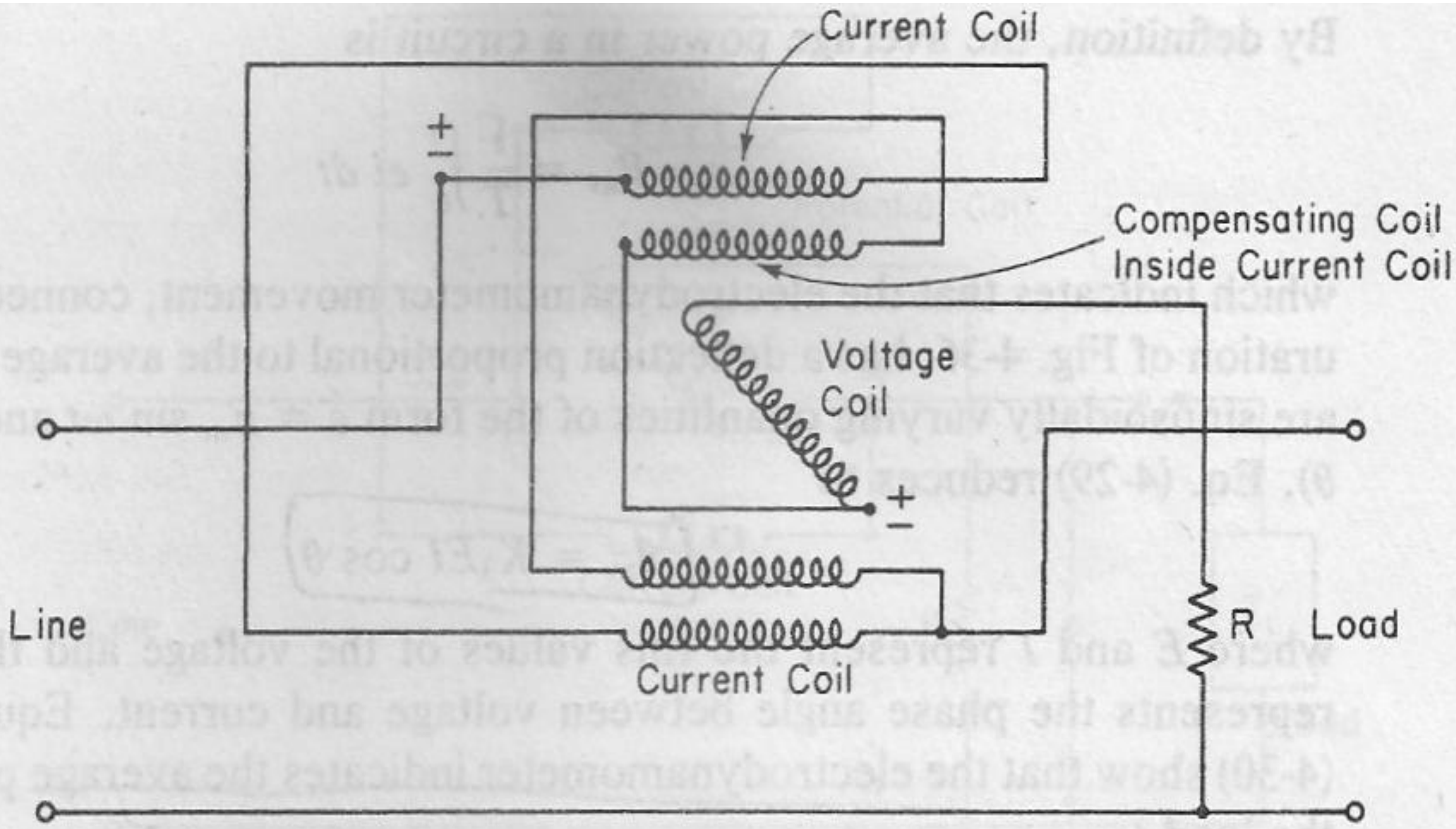

Figure 4-37 Diagram of a compensated wattmeter in which the effect of the current in the potential coil is canceled by the current in the compensating winding.

Electrodynamometers In Power Measurements

- The current coil consists of two windings, each winding having the same number of turns.
- One winding uses heavy wire that carries the load current plus the current for the potential coil.
- The other winding uses thin wire and carries only the current to the potential coil.
- This current, however, is in a direction opposite to the current in the heavy winding, causing a flux that opposes the main flux.
- The effect of i_p is therefore canceled out, and the wattmeter indicates the correct power.

Watthour Meter

- The watthour meter is not often found in a laboratory situation but it is widely used for the commercial measurement of electrical energy.
- It is extensively used at
  - Houses
  - Institutes
  - Industries
  - Power Generation/Distribution Stations

Watthour Meter

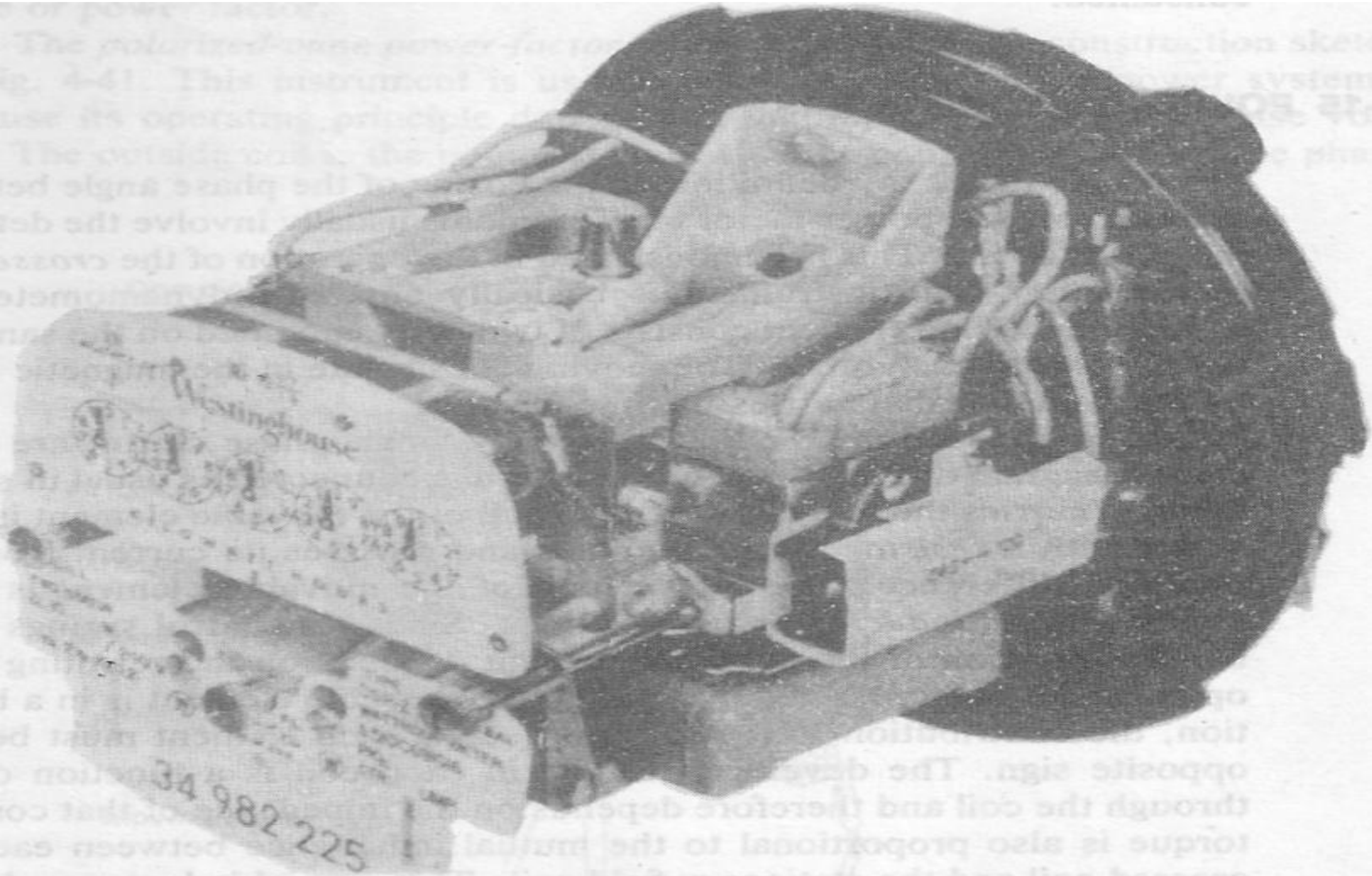

Figure 4-39 Watthour meter for industrial or domestic application. (Courtesy of Westinghouse Electric Corporation.)

Watthour Meter

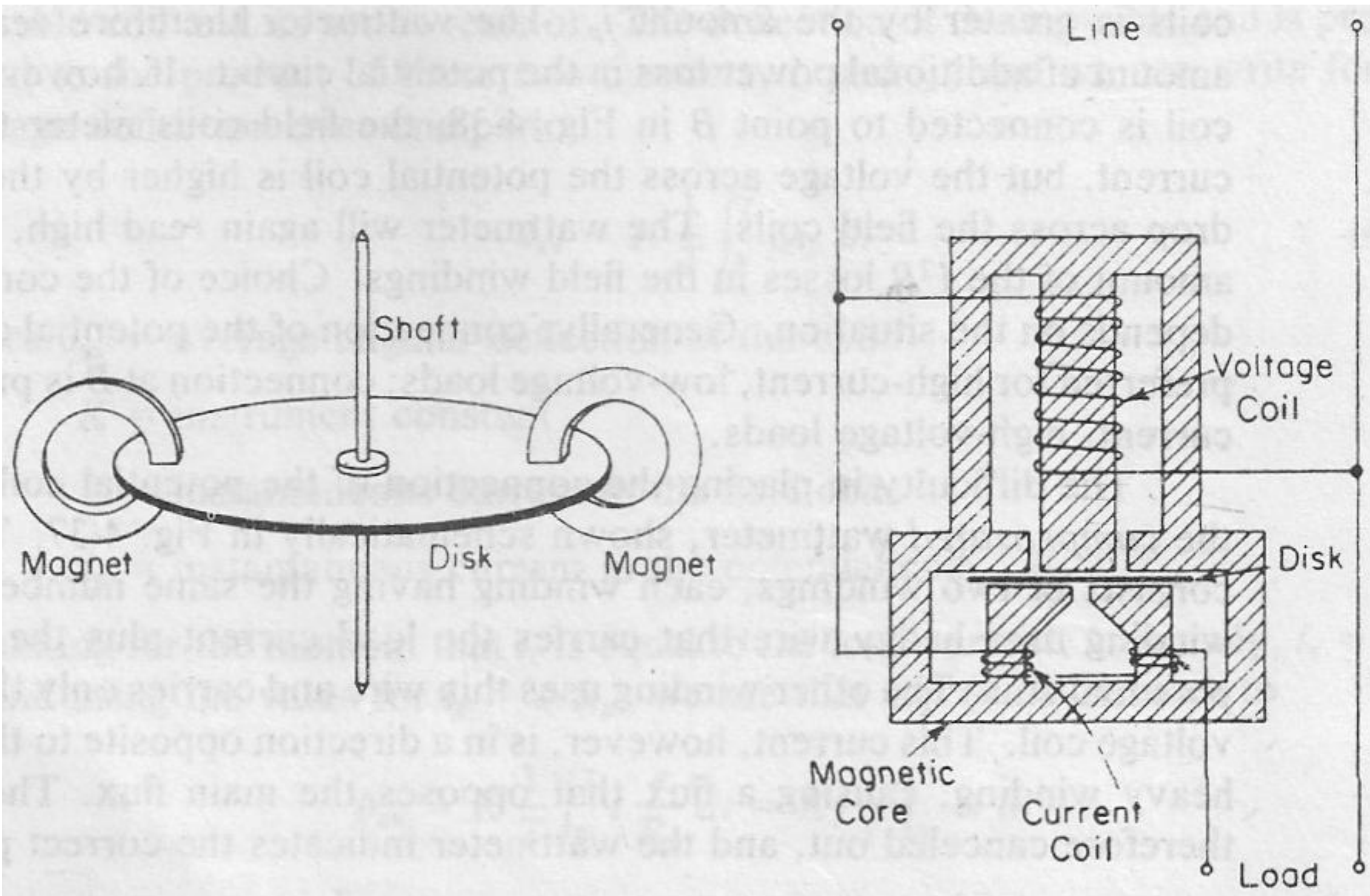

Figure 4-38 Elements of a single-phase watthour meter.

Watthour Meter

- The current coil is connected in series with the line, and the voltage coil is connected across the line.
- Both coils are wound on a metal frame of special design, providing two magnetic circuits.
- A light aluminum disk is suspended in the air gap of the current-coil field, which causes eddy currents to flow in the disk.
- The reaction of the eddy currents and the field of the voltage coil creates a torque (motor action) on the disk, causing it to rotate.

Watthour Meter

- The developed torque is proportional to the field strength of the voltage coil and the eddy currents in the disk
  - which in turn is a function of the field strength of the current coil.
- The number of rotations of the disk is therefore proportional to the energy consumed by the load in a certain time interval, and is measured in terms of kilowatthours (kWh).
  - 1 KWh is called one energy unit
- The shaft that supports the aluminum disk is connected by a gear arrangement to the clock mechanism on the front of the meter, providing a decimally calibrated readout of the number of kWh.
- Damping of the disk is provided by two small permanent magnets located opposite each other at the rim of the disk.

Watthour Meter

- Whenever the disk rotates, the permanent magnets induce eddy currents in it.
- These eddy currents react with the magnetic fields of the small permanent magnets, damping the motion of the disk.
- Calibration of the watthour meter is performed under conditions of full rated load and 10 percent of rated load.
- At full load, the calibration consists *pf* adjustment of the position of the small permanent magnets until the meter reads correctly.
- At very light loads, the voltage component of the field produces a torque that is not directly proportional to the load.

Watthour Meter

- Compensation for the error is provided by inserting a shading coil or plate over a portion of the voltage coil, with the meter operating at 10 percent of rated load.
- Calibration of the meter at these two positions usually provides satisfactory readings at all other loads.
- Measurements of energy in three-phase systems are performed with poly phase watthour meters.
- Each phase of the watthour meter has its own magnetic circuit and its own disk, but all the disks are mounted on a common shaft.
- The developed torque on each disk is mechanically summed
- the total number of revolutions per minute of the shaft is proportional to the total three-phase energy consumed.

Thank you