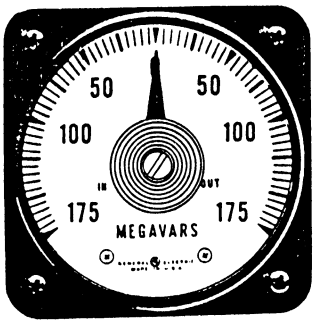


# VARMETERS: THEIR CONNECTION AND CALIBRATION

**WHAT IS A VARMETER?** One will rarely find this name in a dictionary or in any of the older electrical measurement textbooks. The name "var" was adopted for the unit of reactive power at a meeting of the International Electrotechnical Commission at Stockholm in 1930. Thus, a varmeter is an instrument for measuring this quantity.

While actually an imaginary quantity, the var has been defined as the (average) rate of exchange of energy between the associated electromagnetic and/or electrostatic fields and the source of excitation. If one follows the old practice of identifying "leading vars" or "lagging vars" for inductive or capacitive loads respectively, the situation becomes confusing on tie lines where the active power may flow in either direction. Thus, one could not tell whether an instrument indication meant "lagging vars-out" or "leading vars-in" since the indications would be alike.

The present and clearer concept regards all reactive power as inductive or "magnetizing vars," with the generator supplying these "magnetizing vars" to an inductive load, or a capacitor or over-excited synchronous motor supplying these vars to magnetize the field of the generator. The term "magnetizing" has been dropped from most varmeter scales and they are simply marked "Vars," "Kilovars," or "Megavars," "In" or "Out." The most normal condition of "Vars-Out" is now associated with an upscale deflection of the instrument pointer on standard varmeters.

**VARMETER USE.** A varmeter may be used in conjunction with a wattmeter simply to measure power factor. This combination has several advantages over the use of a conventional power-factor meter:

1. Varmeters are accurate over the entire current range while the accuracy of power-factor meters is influenced by the magnitude of the current.
2. Polyphase wattmeters and varmeters are usually accurate on unbalanced loads (especially on the standard recommended combinations), whereas the conventional polyphase power-factor meter can be used only on balanced circuits. (Special instruments are available for measurement of power factor on unbalanced circuits, but they are complex and expensive.)
3. A slight deviation from unity power factor is more noticeable on a varmeter than on a power-factor meter. For example, a power factor of 98 percent will give a varmeter reading equal to about 20 percent of the active power.

One of the principal uses of varmeters is to help control the distribution of reactive power between generators in a power plant and also between plants and systems. While a varmeter reading represents an imaginary quantity, this quantity is still controlled and dispatched in the same manner as active power to make most efficient use of generators, transformers, and tie lines by distributing magnetizing current equitably and keeping down $I^2R$ or heating losses.

**VARMETER CONSTRUCTION.** A varmeter is built in exactly the same manner as a conventional wattmeter and its special features, aside from a scale marked in "Vars" or "Kilovars," may consist of a built-in phase-shifting network, an external phase-shifting means such as a double auto-transformer, or simply a different method of connecting in the circuit than is employed to measure active power.

Since a varmeter must measure $EI \sin \theta$ (where E is line voltage, I is line current, and $\theta$ is the phase angle between them) instead of $EI \cos \theta$ as in a wattmeter, the potential circuit must have a quadrature relationship with the normal wattmeter potential, obtained by lagging it 90 degrees. Thus a varmeter either single phase or polyphase, must read "zero" at unity power factor.

**VARMETER CONNECTIONS.** Methods of obtaining the quadrature relationship, and the specific connections to achieve this condition, are:

A. For single-phase varmeters on single-phase circuits.
   1. A resistance-inductance phase-shifting network.
   2. A resistance-capacitance phase-shifting network.
B. For single-phase varmeters on polyphase circuits.
   1. Simply cross-phasing wattmeters of standard construction.
C. For polyphase varmeters.
   1. Use of wattmeters with external phase-shifting transformers.
   2. Simply cross-phasing wattmeters (as on 4-wire 3-phase circuits).

In some instances, such as a 3-wire 3-phase wattmeter used with an external phase-shifting transformer, standard wattmeter calibration is used and the instrument may read "watts" by itself or "vars" when switched on to the phase-shifting transformer. In other cases, however, a specially calibrated instrument must be used to measure vars correctly.

Voltage magnitudes are important here and must be taken into consideration in computing the calibrating watts for full-scale adjustment.

For accurate measurement of vars it is important that varmeter potential be lagged 90 degrees from the corresponding wattmeter potential. While it is theoretically possible to measure vars by providing a quadrature relationship between current and potential (at unity power factor) it may introduce a fictitious voltage and magnify errors due to unbalanced current or potential. Single-phase varmeters, using an artificial phase-shifting network to obtain the required quadrature relationship, are very sensitive to frequency variations, and, therefore, must be used on circuits whose frequency is held very close to the value used during calibration.

**VARMETER CALIBRATION.** Polyphase varmeters are the simplest to calibrate since they are nearly always wattmeters with external phase-shifting

arrangements. Thus the instrument is adjusted or calibrated alone (i.e., without these external devices) in the same manner as wattmeters. They are, therefore, marked with a value of Calibrating Watts, the value of single-phase watts to be applied to the instrument with all current coils in series and potential coils in multiple. External phase-shifting transformers are checked separately, by measuring the relative voltages between the various terminals (or transformer taps).

Single-phase varmeters must be checked as varmeters since the phase-shifting network comprises a vital part of the instrument circuitry. With voltage and current held exactly in phase (unity power factor) the resistance-inductance or resistance-capacitance network is adjusted until the instrument reads *zero*. Then, adjusting the power factor to zero (by a rotatable phase shifter, for example) so that a wattmeter in the circuit will also read zero, the instrument is adjusted and calibrated using a product of volts times amperes corresponding to the particular value of vars on the scale, or in case it is used with current or potential transformers:

$$\text{Calibrating V-A} = \frac{\text{Scale in vars}}{\text{C.T. Ratio x P.T. Ratio}}$$

Methods of connecting indicating and recording varmeters are listed in the table.

## Methods of Connecting Indicating and Recording Varmeters

| No. | Instrument Type | Wire | Phase | Transformers | Remarks |
|---|---|---|---|---|---|
| 1. | Single Element Varmeter (Illus.) | 2 | 1 | Any | Ext. Impedor Std. |
| 2. | " " " | 3 | 2 | 1 PT 1 CT | Cross Phased |
| 3. | " " " | 4 | 2 | " " | " " |
| 4. | " " " (Illus.) | 3 | 3 | " " | " " |
| 5. | " " " | 4 | 3 | " " | " " |
| 6. | " " " | 4 | 3 | " " | Ext. Impedor |
| 7. | " " " | 6 | 6 | " " | Cross Phased |
| 8. | 2-Element Varmeter | 3 | 2 | 2 PT 2 CT | Cross Phased Std. |
| 9. | " " " | 4 | 2 | " " | " " |
| 10. | " " " | 3 | 3 | " " | Ph. Shift Transf. Std. |
| 11. | " " " | 3 | 3 | " " | Cross Phased |
| 12. | " " " | 3 | 3 | 2 PT 3 CT | CTs in Δ Cross Ph. |
| 13. | " " " | 4 | 3 | 3 PT 3 CT | CTs in Δ Cross Ph. |
| 14. | " " " | 4 | 3 | " " | CTs in Δ Ph. Shift Transf. |
| 15. | " " " | 4 | 3 | 2 PT 3 CT | " " " " " |
| 16. | 3 Curr-2 Potential Varmeter | 4 | 3 | 3 PT 3 CT | Cross phased–Std. |
| 17. | " " " " | 4 | 3 | 3 PT 3 CT | (1 CT in Common) |
| 18. | " " " " | 4 | 3 | 2 PT 3 CT | Phase Shift Transf. |
| 19. | " " " " | 4 | 3 | 3 PT 3 CT | " " " |
| 20. | " " " " | 4 | 3 | No PT 3 CT | Cross-Phased |
| 21. | " " " " | 6 | 6 | 2 PT 3 CT | " " |

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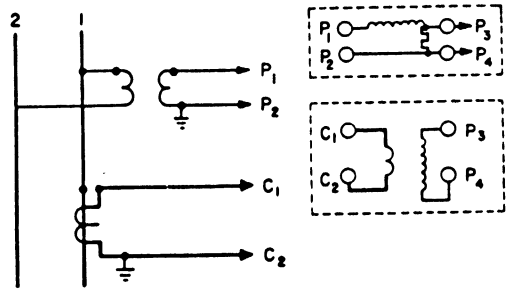
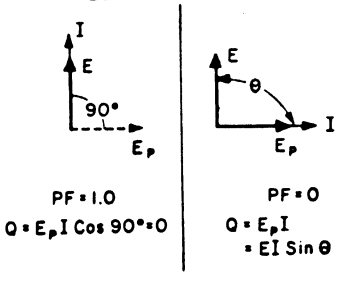
**Metering:** 1
Vars on single phase, 2-wire circ.
**Transformers:**
1 potential, 1 current
**Instrument:**
Single-element varmeter
**Special Features:**
External phase-shift impedor
**Limitations:**
One frequency only

Cal. V-A =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio}}$$




VECTOR DIAGRAMS




PF = 1.0
Q = $E_p I \cos 90° = 0$

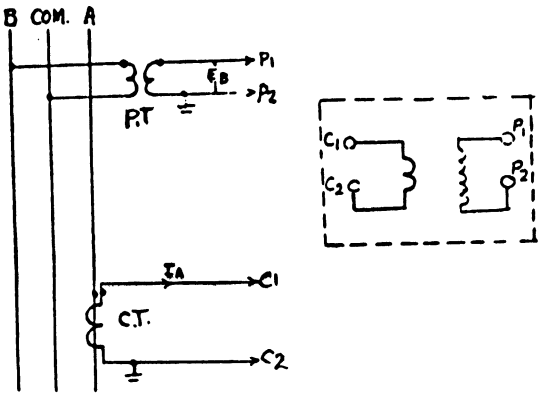
PF = 0
Q = $E_p I$
= $EI \sin \theta$

---

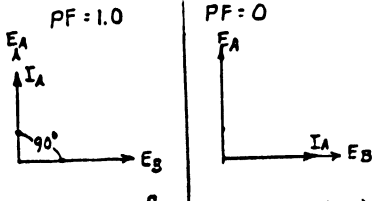
**Metering:** 2
Vars on 2 Ph. 3 W.
**Transformers:**
1 P.T. 1 C.T.
**Instrument:**
Single-element varmeter
**Special Features:**
Calibration only
**Limitations:**
Balanced Loads & Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2}$$




VECTOR DIAGRAMS




VARS = $E_B I_A \cos 90°$
= $EI \sin 0° = 0$

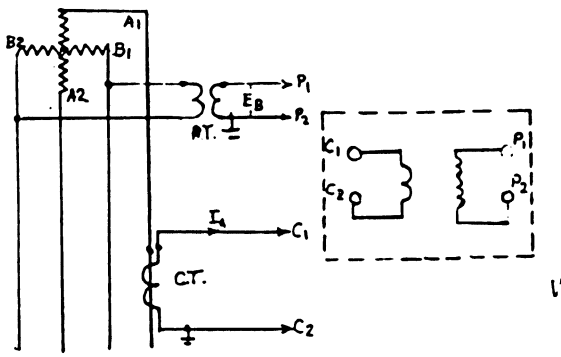
VARS = $E_B I_A$ (x 2)
= $2EI \sin 90° = 2EI$

Metering:
Vars on 2 Ph. 4 W.
Transformers:
1 P.T. 1 C.T.
Instrument:
Single-element varmeter
Special Features:
Calibration only
Limitations:
Balanced Loads & Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2}$$

3

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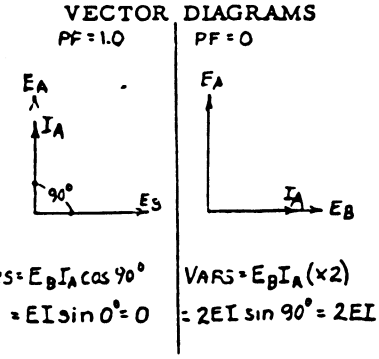



$VARS = E_B I_A \cos 90°$
$= EI \sin 0° = 0$

$VARS = E_B I_A (\times 2)$
$= 2EI \sin 90° = 2EI$

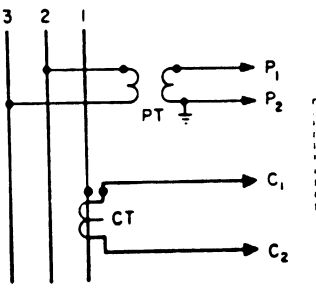
---

Metering:
Vars on 3 wire, 3 phase
Transformers:
1 potential, 1 current
Instrument:
Single-element varmeter
Special Features:
Calibration only
Limitations:
Bal. currents and voltages

Cal. V-A =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times \sqrt{3}}$$

4

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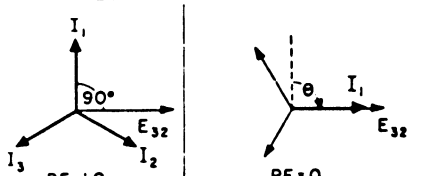


$Q = E_{32} I_1 \cos 90° = 0$

$Q = E_{32} I_1$
Multiplying Scale by $\sqrt{3}$
$= \sqrt{3} EI = \sqrt{3} EI \sin \theta$

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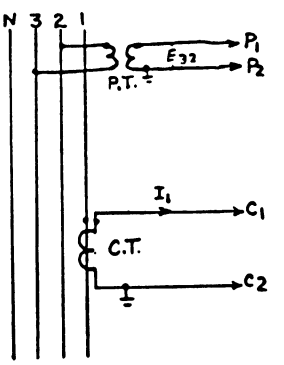
Metering:
Vars on 3 Ph. 4 W.
Transformers:
1 P.T. 1 C.T.
Instrument:
Single-element varmeter
Special Features:
Calibration only
Limitations:
Bal. currents and voltages

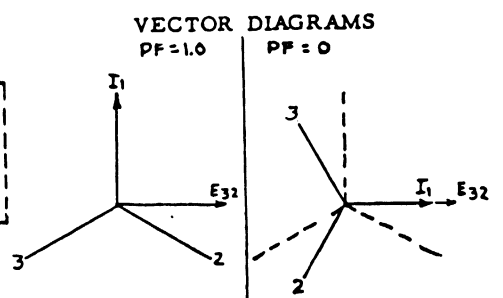
Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times \sqrt{3}}$$

5




VECTOR DIAGRAMS




$VARS = E_{32} I_1 \cos 90°$
$= EI \sin 0° = 0$

$VARS = E_{32} I_1 \cos 0° (\times \sqrt{3})$
$= \sqrt{3} EI \sin 90°$
$= \sqrt{3} EI$

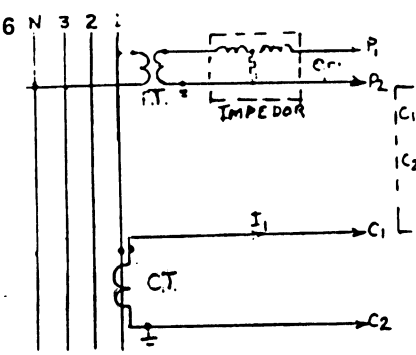
---

Metering:
Vars on 3 Ph. 4 W.
Transformers:
1 P.T. 1 C.T.
Instrument:
Single Ph. Varmeter
Special Features:
Requires Impedor
Limitations:
Bal. Loads & Voltages
Controlled Freq.

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 3}$$

6

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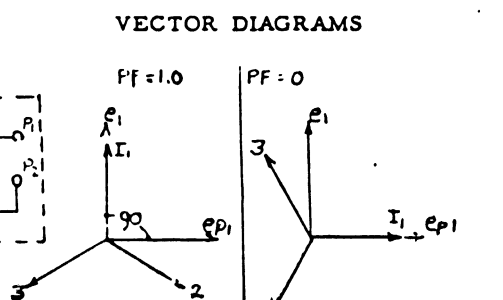



$VARS = e_{p1} I_1 \cos 90°$
$= eI \sin 0° = 0$

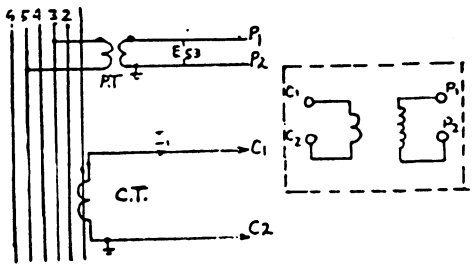
$VARS = e_{p1} I_1 \cos 0° (\times 3)$
$= 3eI \sin 90°$
$= 3eI$

Metering:
Vars on 6 Ph. 6 W.
Transformers:
1 P.T. 1 C.T.
Instrument:
Single-element varmeter
Special Features:
Calibration only
Limitations:
Bal. Loads & Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2\sqrt{3}}$$

7

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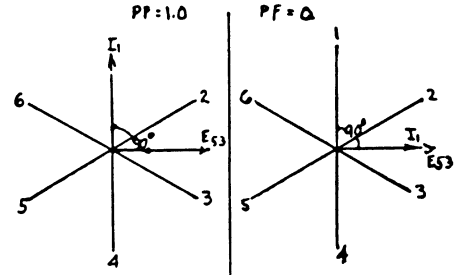



VARS = $E_{53} I_1 \cos 90°$
$= EI \sin 0° = 0$

VARS = $E_{53} I_1 \cos 0° (\times 2\sqrt{3})$
$= 2\sqrt{3}\, EI \sin 90°$
$= 2\sqrt{3}\, EI$ or $6e^{-}$

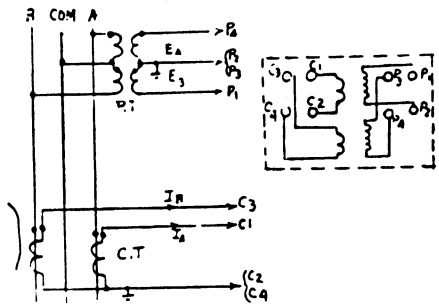
---

Metering:
Vars on 2 Ph. 3 W.
Transformers:
2 P.T. 2 C.T.
Instrument:
2-element varmeter
Special Features:
None
Limitations:
Bal. Voltages (Std. Conn.)

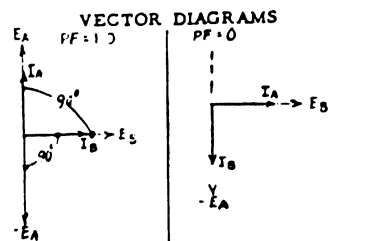
Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2}$$

8




VECTOR DIAGRAMS




VARS = $E_B I_A \cos 90° + E_A I_B \cos 90°$
$= EI \sin 0° + EI \sin 0° = 0$

VARS = $E_B I_A \cos 0° + E_A I_B \cos 0°$
$= EI \sin 90° + EI \sin 90°$
$= 2EI$

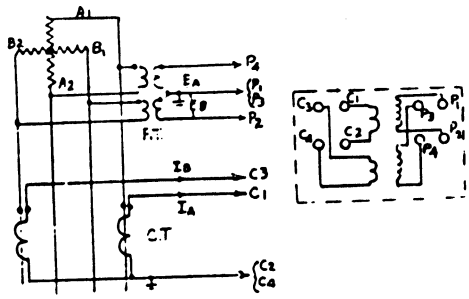
---

Metering:
Vars on 2 Ph. 4 W.
Transformers:
2 P.T. 2 C.T.
Instrument:
2-element varmeter
Special Features:
None
Limitations:
Bal. Voltages (Std. Conn.)

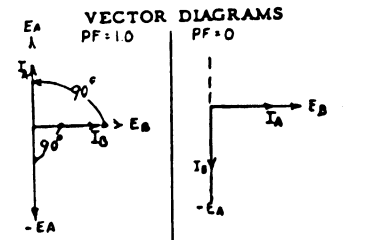
Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2}$$

9




VECTOR DIAGRAMS




VARS = $E_B I_A \cos 90° + E_A I_B \cos 90°$
$= EI \sin 0° + EI \sin 0°$
$= 0$

VARS = $E_B I_A \cos 0° + E_A I_B \cos 0$
$= EI \sin 90° + EI \sin 90°$
$= 2EI$

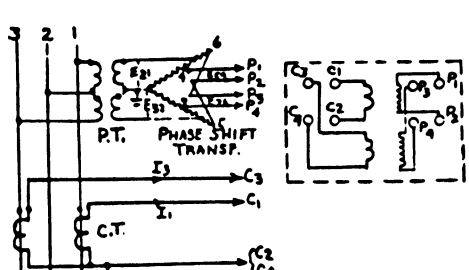
---

Metering:
Vars on 3 Ph. 3 W.
Transformers:
2 P.T. 2 C.T.
4 Phase Shift Transf.
Instrument:
2-element varmeter
Special Features:
None
Limitations:
Bal. Voltages (Std. Conn.)

Cal. Watts = PER EL.

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2}$$

10

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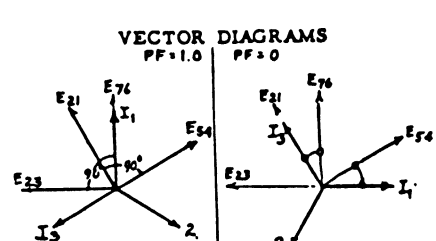



VARS = $E_{54} I_1 \cos 60° - E_{76} I_3 \cos 60°$
$= EI \sin 30° - EI \sin 30° = 0$

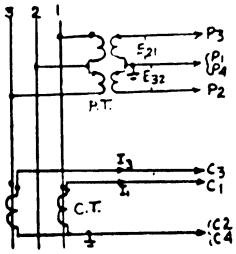
VARS = $E_{54} I_1 \cos 30° + E_{76} I_3 \cos 30°$
$= EI \sin 60° + EI \sin 60°$
$= \sqrt{3}\, EI$

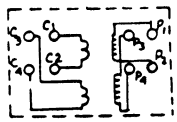
11

Metering:
Vars on 3 Ph. 3 W.
Transformers:
2 P.T. 2 C.T.
Instrument:
2-element varmeter
Special Features:
Calibration only
Limitations:
Bal. currents & voltages

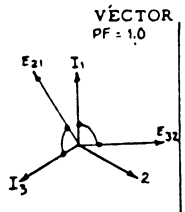
Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times \sqrt{3}}$$



VECTOR DIAGRAMS




$VARS = E_{32}I_1\cos 90° + E_{21}I_3\cos 90°$
$= EI\sin 0° + EI\sin 0° = 0$

$VARS = (E_{32}I_1\cos 0° + E_{21}I_3\cos 0°) \times \sqrt{3}/2$
$= \sqrt{3}/2\,(EI\sin 90° + EI\sin 90°)$
$= \sqrt{3}\,EI$

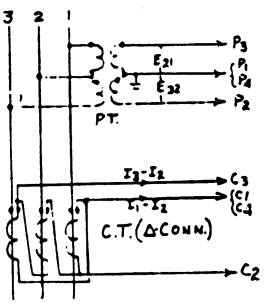
---

12

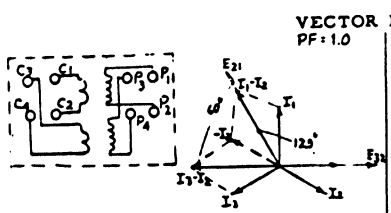
Metering:
Vars on 3 Ph. 3 W.
Transformers:
2 P.T. 3 C.T.-Δ-Conn.
Instrument:
2-element varmeter
Special Features:
Spec. Calib.-8.66A Coils
Limitations:
Bal. Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2/\sqrt{3}}$$




VECTOR DIAGRAMS




$VARS = E_{21}I_{3-2}\cos\omega° - E_{32}I_{1-2}\cos 60°$
$= EI\sin 30° - EI\sin 30°$
$= 0$

$VARS = (E_{21}I_{3-2}\cos 30° + E_{32}I_{1-2}\cos 30°)$ $(\times 1/\sqrt{3})$
$= (E\sqrt{3}I\sin 60° + E\sqrt{3}I\sin 60°)$ $(\times 1/\sqrt{3})$
$= (3/2\,EI + 3/2\,EI)\,1/\sqrt{3} = \sqrt{3}\,EI$

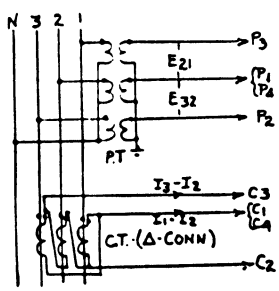
---

13

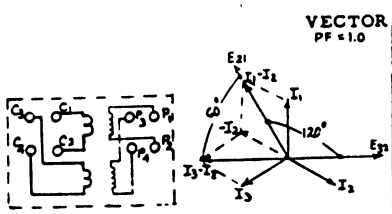
Metering:
Vars on 3 Ph. 4 W.
Transformers:
3 P.T. 3 C.T.-Δ-Conn.
Instrument:
2-element varmeter
Special Features:
Spec. Calib.-8.66A Coils
Limitations:
Bal. Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2/\sqrt{3}}$$




VECTOR DIAGRAMS




$VARS = E_{21}I_{3-2}\cos\omega° - E_{32}I_{1-2}\cos 60°$
$= EI\sin 30° - EI\sin 30°$
$= 0$

$VARS = (E_{21}I_{3-2}\cos 30° + E_{32}I_{1-2}\cos 30°)$ $(\times 1/\sqrt{3})$
$= (E\sqrt{3}I\sin 60° + E\sqrt{3}I\sin 60°)$ $(\times 1/\sqrt{3})$
$= (3/2\,EI + 3/2\,EI)\,1/\sqrt{3} = \sqrt{3}\,EI$

---

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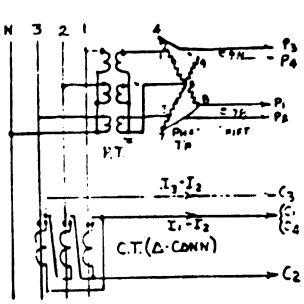
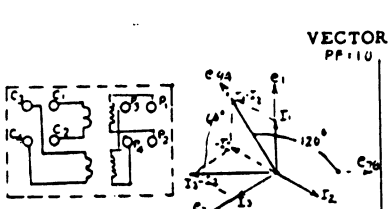
Metering:
Vars on 3 Ph. 4 W.
Transformers:
3 P.T. 3 C.T. (Δ-Conn.)
Phase-Shift Transf.
Instrument:
2-element varmeter
Special Features:
8.66 Amp Cur Coils
Limitations:
Bal. Voltages

Gal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2}$$




VECTOR DIAGRAMS




$VARS = e_{aa}I_{3-2}\cos 60° - e_{76}I_{1-2}\cos 60°$
$= e\sqrt{3}I\sin 30° - e\sqrt{3}I\sin 30°$
$= 0$

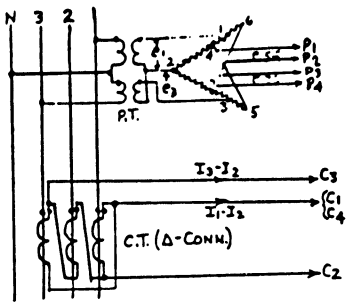
$VARS = e_{aa}I_{3-2}\cos 30° + e_{76}I_{1-2}\cos 30°$
$= e\sqrt{3}I\sin 60° + e\sqrt{3}I\sin 60°$
$= \sqrt{3}eI\,\frac{\sqrt{3}}{2} + \sqrt{3}eI\,\frac{\sqrt{3}}{2} = 3eI$

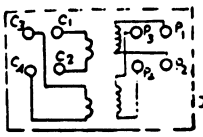
Metering:
Vars on 3 Ph. 4 W.
Transformers:
2 P.T. 3 C.T. (Δ-Conn.)
Phase-Shift Transf.
Instrument:
2-element varmeter
Special Features:
8.66 Amp Cur Coils
Limitations:
Bal. Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 2}$$

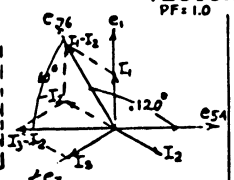
15



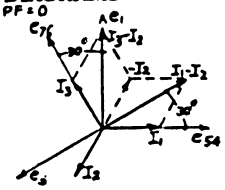
VECTOR DIAGRAMS

PF = 1.0



$VARS = e_{76} I_{3-2} \cos 60° - e_{54} I_{1-2} \cos 60°$
$= e\sqrt{3} I \sin 30° - e\sqrt{3} I \sin 30°$
$= 0$

PF = 0



$VARS = e_{76} I_{3-2} \cos 30° + e_{54} I_{1-2} \cos 30°$
$= e\sqrt{3} I \sin 60° + e\sqrt{3} I \sin 60°$
$= \sqrt{3} eI \frac{\sqrt{3}}{2} + \sqrt{3} eI \frac{\sqrt{3}}{2} = 3eI$

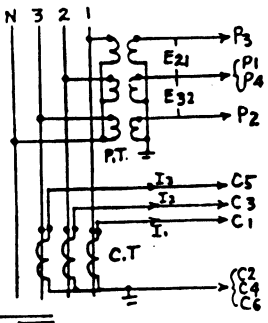
---

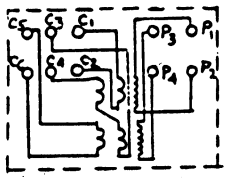
Metering:
Vars on 3 Ph. 4 W.
Transformers:
3 P.T. 3 C.T.
Instrument:
3-Current 2-Pot. Varmeter
Special Features:
Calibration only
Limitations:
Bal. Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 4/\sqrt{3}}$$

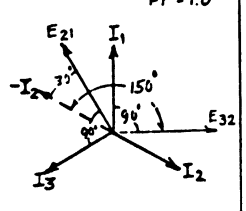
16



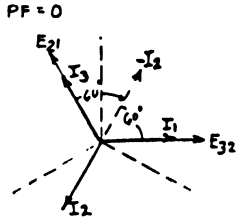
VECTOR DIAGRAMS

PF = 1.0



$VARS = E_{32} I_1 \cos 90° - E_{32} I_2 \cos 30°$
$+ E_{21} I_3 \cos 90° + E_{21} I_2 \cos 30°$
$= EI \sin 0° - EI \sin 60°$
$+ EI \sin 0° + EI \sin 60° = 0$

PF = 0



$VARS = (E_{32} I_1 + E_{32} I_2 \cos 60°$
$+ E_{21} I_3 + E_{21} I_2 \cos 60°) \times 1/\sqrt{3}$
$= 1/\sqrt{3} (EI + EI \sin 30° + EI$
$+ EI \sin 30°) = \sqrt{3}\, EI$

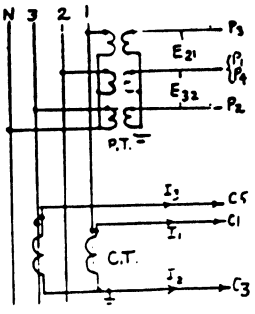
---

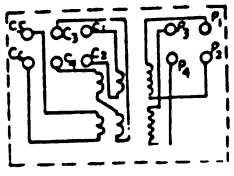
Metering:
Vars on 3 Ph. 4 W.
Transformers:
3 P.T. 2 C.T.
Instrument:
3-Current 2-Pot. Varmeter
Special Features:
Calibration only
Limitations:
Bal. Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 4/\sqrt{3}}$$

17

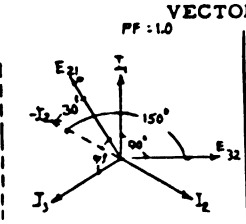


CONNECT $C_2$, $C_4$ & $C_6$ TERMINALS TOGETHER

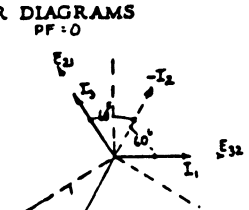
VECTOR DIAGRAMS

PF = 1.0



$VARS = E_{32} I_1 \cos 90° - E_{32} I_2 \cos 30°$
$+ E_{21} I_3 \cos 90° + E_{21} I_2 \cos 30°$
$= EI \sin 0° - EI \sin 60°$
$+ EI \sin 0° + EI \sin 60° = 0$

PF = 0



$VARS = (E_{32} I_1 + E_{32} I_2 \cos 60°$
$+ E_{21} I_3 + E_{21} I_2 \cos 60°) \times 1/\sqrt{3}$
$= 1/\sqrt{3} (EI + EI \sin 30° + EI$
$+ EI \sin 30°) = \sqrt{3}\, EI$

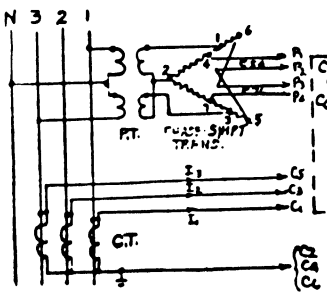
---

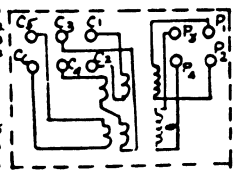
Metering:
Vars on 3 Ph. 4 W.
Transformers:
2 P.T. 3 C.T.
Phase-Shift Transf.
Instrument:
3-Current 2-Pot. Varmeter
Special Features:
Calibration only
Limitations:
Bal. Voltages

Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 4}$$

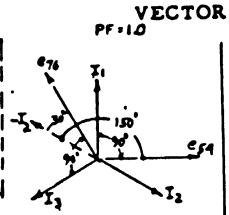
18



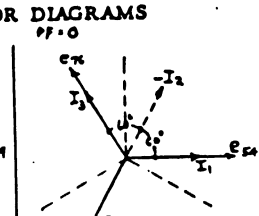
VECTOR DIAGRAMS

PF = 1.0



$VARS = e_{54} I_1 \cos 90° - e_{54} I_2 \cos 30°$
$+ e_{76} I_3 \cos 90° + e_{76} I_2 \cos 30°$
$= eI \sin 0° - eI \sin 60°$
$+ eI \sin 0° + eI \sin 60° = 0$

PF = 0



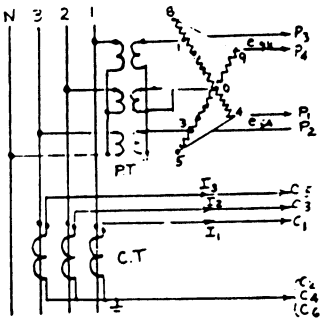
$VARS = e_{54} I_1 + e_{54} I_2 \cos 60°$
$+ e_{76} I_3 + e_{76} I_2 \cos 60°$
$+ eI + eI \sin 30° + eI$
$+ eI \sin 30° = 3eI$

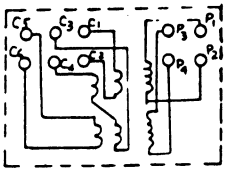
19

Metering:
Vars on 3 Ph. 4 W.
Transformers:
3 P.T. 3 C.T.
Phase-Shift Transf.
Instrument:
3-Current 2-Pot. Varmeter
Special Features:
None (Std. Conn.)
Limitations:
Bal. Voltages

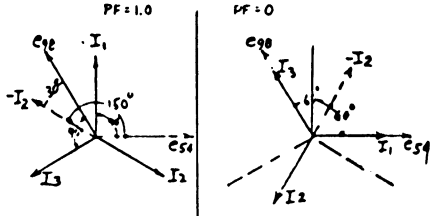
Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 4}$$



VECTOR DIAGRAMS




$VARS = e_{54}I_1\cos 90° - e_{54}I_2\cos 30° + e_{98}I_3\cos 90° + e_{98}I_2\cos 30°$
$= eI\sin 0° - eI\sin 60° + eI\sin 0° + eI\sin 60° = 0$

$VARS = e_{54}I_1 + e_{54}I_2\cos 60° + e_{98}I_3 + e_{98}I_2\cos 60°$
$= eI + eI\sin 30° + eI + eI\sin 30° = 3eI$

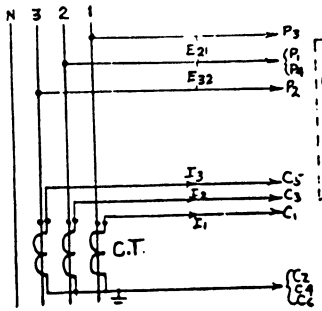
---

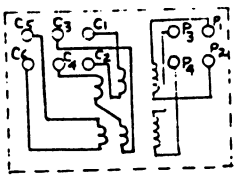
20

Metering:
Vars on 3 Ph. 4 W.
Transformers:
No P.T. 3 C.T.
Instrument:
3-Current 2-Pot. Varmeter
Special Features:
Calibration only
Limitations:
Bal. Voltages (Std. Conn.)

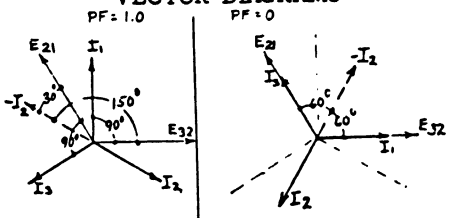
Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 4/\sqrt{3}}$$



VECTOR DIAGRAMS




$VARS = E_{21}I_3\cos 90° + E_{21}I_2\cos 30° + E_{32}I_1\cos 90° - E_{32}I_2\cos 30°$
$= EI\sin 0° + EI\sin 60° + EI\sin 0° - EI\sin 60° = 0$

$VARS = (E_{21}I_3 + E_{21}I_2\cos 60° + E_{32}I_1 + E_{32}I_2\cos 60°) \times 1/\sqrt{3}$
$= 1/\sqrt{3}(EI + EI\sin 30° + EI + EI\sin 30°) = 3EI/\sqrt{3}$
$= \sqrt{3}EI$ or $3eI$

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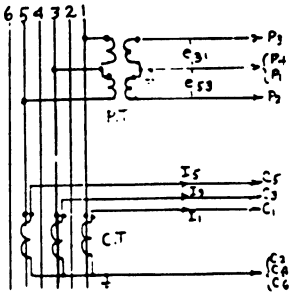
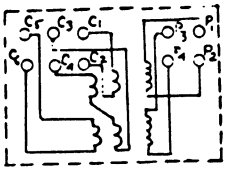
21

Metering:
Vars on 6 Ph. 6 W.
Transformers:
2 P.T. 3 C.T.
Instrument:
3-Current 2-Pot Varmeter
Special Features:
Calibration only
Limitations:
Bal. Loads & Voltages

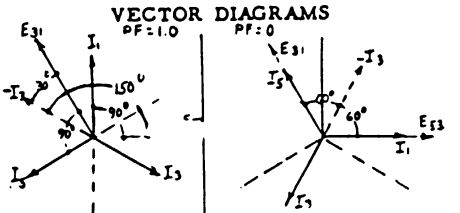
Cal. Watts =

$$\frac{\text{Scale in Vars}}{\text{P.T. Ratio} \times \text{C.T. Ratio} \times 8/\sqrt{3}}$$



VECTOR DIAGRAMS




$VARS = E_{31}I_5\cos 90° + E_{31}I_3\cos 30° + E_{53}I_1\cos 90° - E_{53}I_3\cos 30°$
$= EI\sin 0° + EI\sin 60° + EI\sin 0° - EI\sin 60° = 0$

$VARS = (E_{31}I_5 + E_{31}I_3\cos 60° + E_{53}I_1 + E_{53}I_3\cos 60°) \times 2/\sqrt{3}$
$= 2/\sqrt{3}(EI + EI\sin 30° + EI + EI\sin 30°) = 2(3EI)/\sqrt{3}$
$= 2\sqrt{3}EI = 6eI$