Electrical Equipment - Course 230.2

ELECTRICAL METERING: PART 2

VOLTAGE COUPLERS AND METERS

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1. OBJECTIVE

The student must be able to:

1.1 For a capacitor voltage transformer:

(a) State its purpose.
(b) Describe its normal operation.
(c) State the three safety precautions.

1.2 For a Bushing capacitor voltage transformer:

(a) State its purpose.
(b) Describe its normal operation.
(c) State the three safety precautions.

1.3 Explain how the outputs from VT's and CT's are used to give indications of:

(a) Voltage.
(b) Current.
(c) Active Power.
(d) Reactive Power.

2. INTRODUCTION

This lesson explains the construction, normal operation and safety precautions associated with **capacitor voltage** transformers and **bushing capacitor voltage transformers.**

The lesson then goes on to explain how the outputs from VT's and CT's are used to give indications of:

- voltage
- current
- active power
- reactive power

3. CAPACITOR VOLTAGE TRANSFORMERS

3.1 Purpose and Principle of Operation

The previous lesson 230.24-1 explained how a wound voltage transformers are used to proportionally reduce the primary circuit voltage to a safe value of $120/\sqrt{3}$ V. Wound voltage transformers are used up to and including 115 kV but above this voltage they become too bulky and too expensive. At 230 kV and 500 kV, capacitor voltage transformers are used in place of wound voltage transformers.

Figure 1 shows the symbol for a capacitor voltage transformer and Figure 2 shows the principle of operation. The line to ground voltage, ($230/\sqrt{3}$ kV in this case) is **divided** by the use of several (4 is a typical number) high voltage capacitors. The voltage produced across the "ground end" capacitor (typically 20 kV) is applied across a small wound potential transformer which reduces the line voltage to $120/\sqrt{3}$ V.

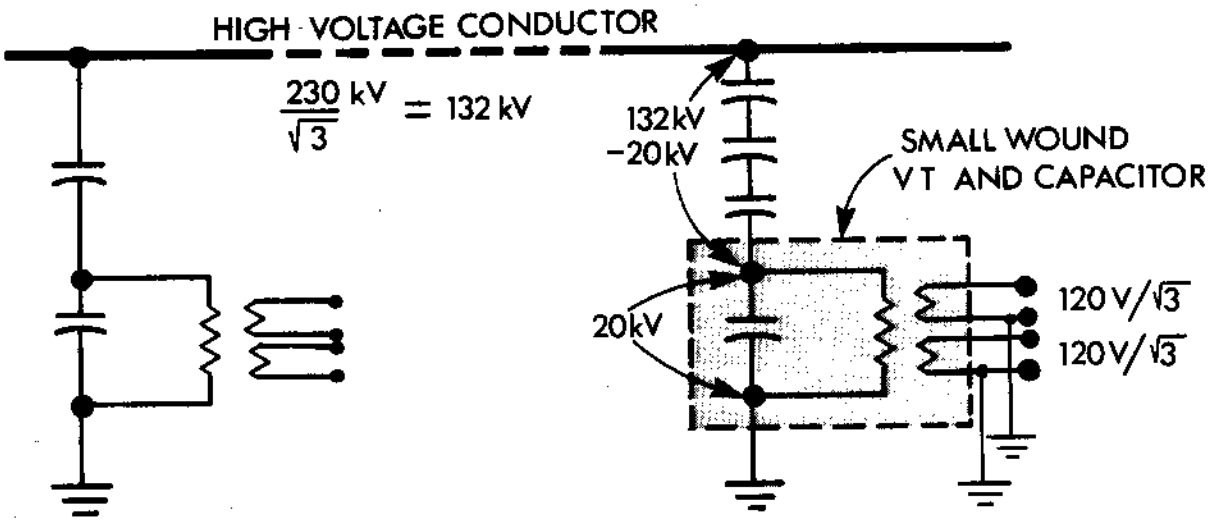

Figure 1: Symbol for a Capacitor Voltage Transformer.

Figure 2: Principle of Operation of a Capacitor Voltage Transformer.

3.2 Safety Precautions

There are three safety precautions associated with a capacitor voltage transformer.

(a) The output (secondary) circuit is fused to prevent damage due to overloads and short circuits.

(b) The secondary windings of the small wound potential transformer must be grounded. This prevents excessive static voltage build-up on the secondary wiring.

(c) The secondary fuses are removed when the circuit is isolated. This prevents any chance of a backfeed to the small potential transformer.

4. BUSHING CAPACITOR VOLTAGE TRANSFORMER

4.1 Purpose and Principle of Operation

The purpose and principle of operation of a bushing capacitor voltage transformer is similar to that of a capacitor voltage transformer. In a bushing potential device, the capacitance of an HV bushing (usually a transformer HV bushing) is used to divide the voltage between line and ground. Figure 3 shows a half section of an HV bushing. Note how concentric metallic foils are used to produce a series of capacitors within the bushing. These foils divide the voltage and ensure equal electrical stressing of the bushing insulation. The outer foil which is at a voltage of approximately 20 kV, is connected to a small wound potential transformer.

Figure 4 shows the symbol for a bushing capacitor voltage transformer and Figure 5 shows the principle of operation.

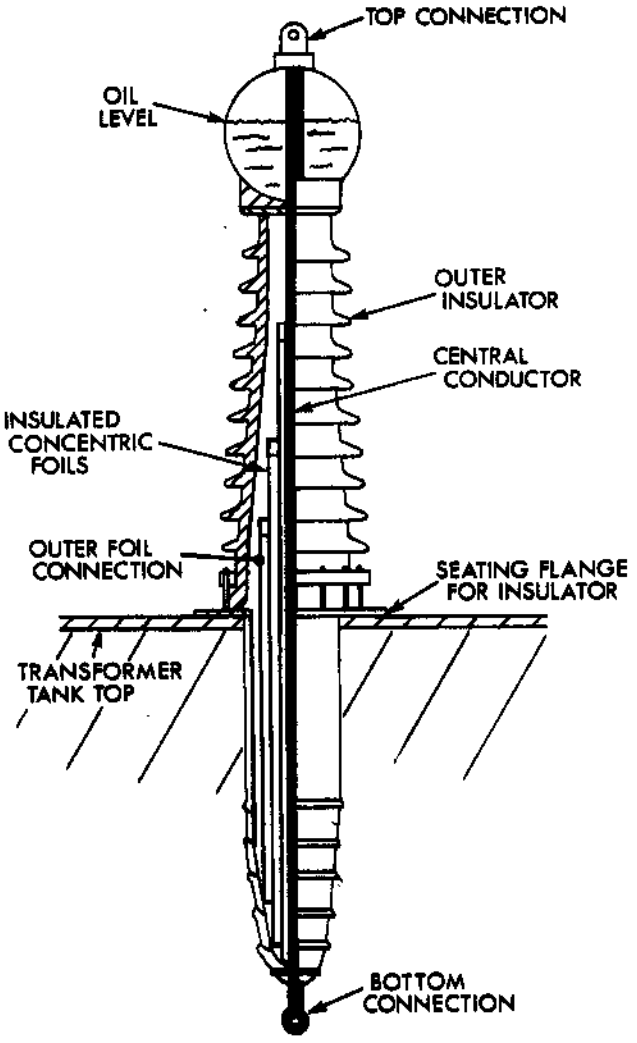

Figure 3: Half Section of a High Voltage Bushing.

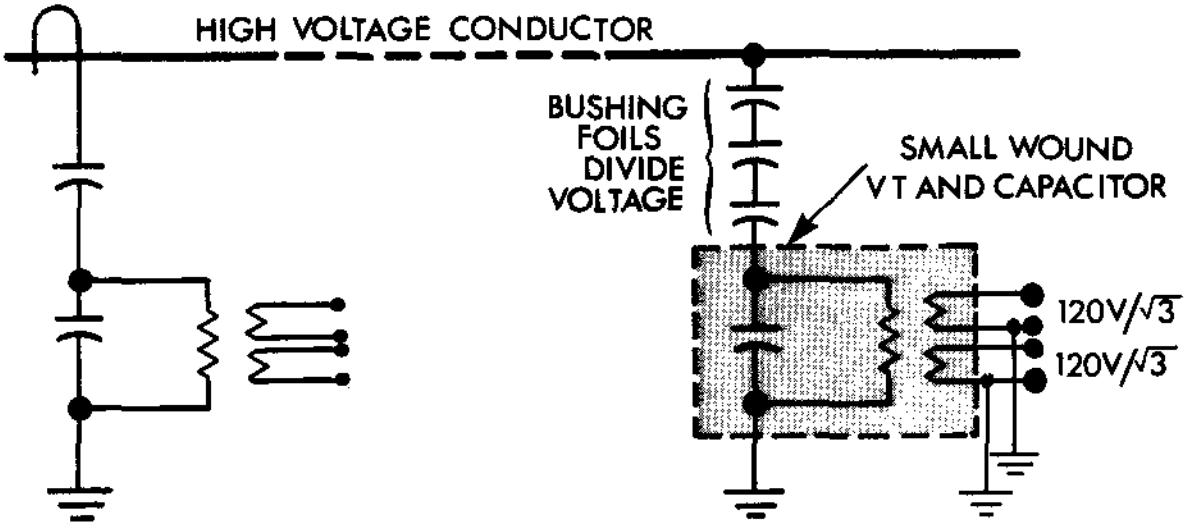

Figure 4: Symbol for a Bushing Capacitor Voltage Transformer.

Figure 5: Principle of Operation of a Bushing Capacitor Voltage Transformer.

4.2 Safety Precautions

Both bushing capacitor voltage transformers and capacitor voltage transformers require the same three safety precautions, ie,

(a) Fusing of the secondary circuit.

(b) Grounding of the secondary circuit.

(c) Removal of secondary fuses, when the circuit is isolated.

5. VOLTAGE CURRENT AND POWER MEASUREMENT

5.1 Voltage Measurement

Figure 6 shows a typical circuit where a wound VT is used to proportionally reduce the line voltage to a safe value. A voltmeter whose rating is $120/\sqrt{3}$ V and scaled 0-24 kV, is connected across the VT secondary terminals. It is not usual to indicate the voltage of all three phases. This is because voltages are usually balanced.

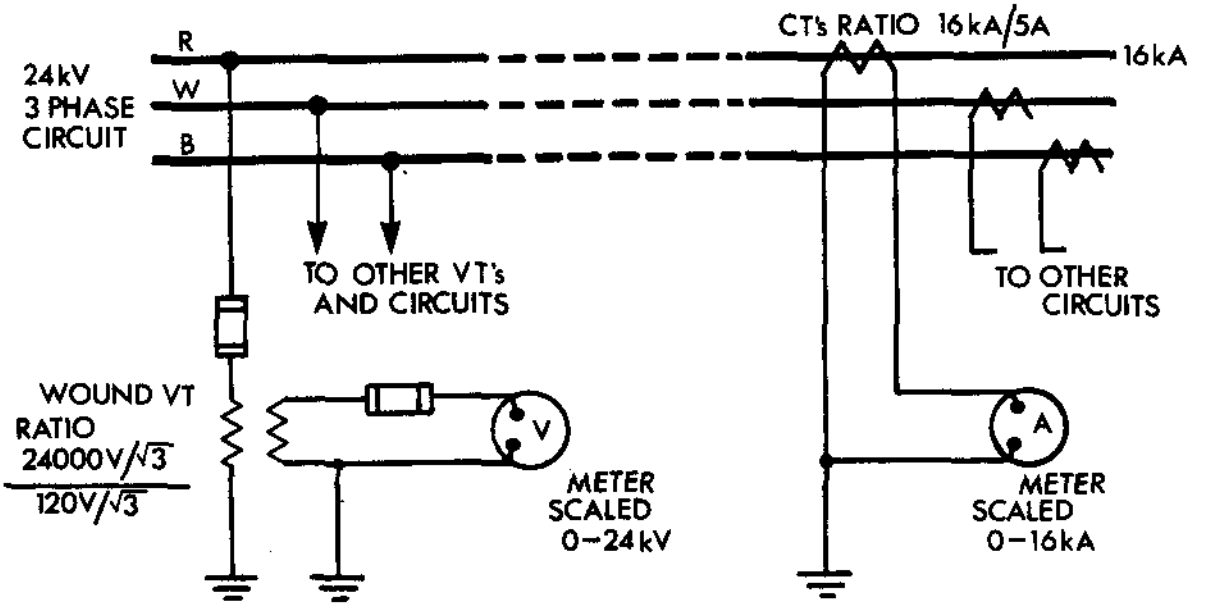

Figure 6: Voltage Measuring Circuit.

Figure 7: Current Measuring Circuit.

5.2 Current Measurement

Figure 7 shows a typical circuit where a CT is used to proportionally reduce the line current to a safe value. An ammeter whose rating is 5A and scaled 0-16 000 A will give a true indication of current. Again, it is not usual to indicate current in all three phases, and this is because the currents are usually balanced.

5.3 Active Power Measurement

For a three phase system, active power P

$$P = \sqrt{3}\ V_L I_L \times \text{Cos}\ \theta \quad \text{Watts}$$

For a wattmeter to measure active power, it has to have an input of both line voltage V_L and line current I_L. The wattmeter computes power by multiplying V_L by I_L and at the same time it takes into account the $\sqrt{3}$ factor and Cos θ, (the angle between V_L and I_L).

5.4 Reactive Power Measurement

For a three phase system, reactive power Q

$$Q = \sqrt{3}\ V_L I_L \times \text{Sin}\ \theta \quad \text{Vars}$$

A var meter is similar in construction to a wattmeter and receives the same voltage and current input signals. The circuit differs from that of a wattmeter in that an external component box is used to turn the voltage vectors through 90°. With the component box the meter reads.

$$Q = \sqrt{3} V_L I_L \text{ Cos } (90-\theta) \quad \text{Vars}$$

$$= \sqrt{3} V_L I_L \text{ Sin } \theta \quad \text{Vars}$$

ASSIGNMENT

1. For a capacitor voltage transformer:

   (a) State its purpose. (Section 3.1)
   (b) Describe its normal operation. (Section 3.1)
   (c) State the safety precautions. (Section 3.2)

2. For a bushing capacitor voltage transformer.

   (a) State its purpose. (Section 4.1)
   (b) Describe its normal operation. (Section 4.1)
   (c) State the safety precautions. (Section 4.2)

3. Draw a labelled diagram showing how the outputs from VT's and CT's are used to give indications of:

   (a) Voltage. (Section 5.1)
   (b) Current. (Section 5.2)

   Include all relevant safety features.

4. Explain how the outputs from VT's and CT's are used to give indications of:

   (a) Active Power. (Section 5.3)
   (b) Reactive Power. (Section 5.4)

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