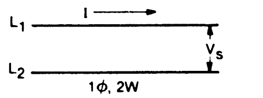
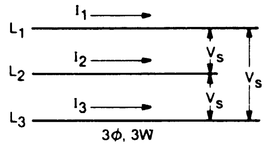
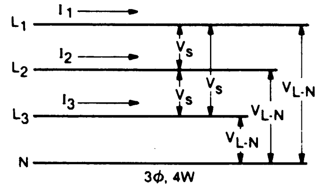
WATTMETER SELECTION

The three electrical systems in most common use today are single-phase/2-wire, 3-phase/3-wire, and 3-phase/4-wire. For simplicity in calculations that follow we assume that the phases are balanced so that the voltages between any two lines are equal, i.e., V_S = System Voltage; also that, in the 3-phase/4-wire system, line-to-neutral voltages (V_{L-N}) are equal. We also assume power factor (PF) to be unity, inasmuch as power factors near 1.0 are common and desirable. In addition, the line currents I_1, I_2, and I_3 are assumed equal and will be designated I. The systems may be depicted, along with specific voltages and currents, as follows:







	1φ2W	3φ3W	3φ4W
Power Watts (W) =	$W = V_S \times I \times PF$	$W = V_S \times I \times PF \times \sqrt{3}$	$W = V_S \times I \times PF \times \sqrt{3}$ $= V_{L-N} \times I \times PF \times 3$ (NOTE: $V_S = V_{L-N}\sqrt{3}$)
The scales for Wattmeters should be selected using:	$W = V_S \times I$	$W = V_S \times I \times \sqrt{3}$	$W = V_S \times I \times \sqrt{3}$ $= V_{L-N} \times I \times 3$

In general, the nearest standard scale value is to be used. These standard values are:
1.0, 1.2, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.5, 8.0 and multiples of 10, 100, 1000, 10,000, or 1,000,000.

Tables I, II, & III list standard full scale (F.S.) values for common voltages and currents.

The integral transducers used with these instruments operate at normal levels of 120 volts and 5 amperes. Higher voltages and currents must be reduced to these values with potential transformers and current transformers. For example, a 7200 volt system (3Φ3W) with 400 ampere capability would require an 7200:120 potential transformer (60:1 ratio) and a 400:5 current transformer (80:1 ratio).

Thus, in this system: V_S = 7200 volts
I = 400 amps
W = 7200 x 400 x $\sqrt{3}$ = 4,988,306 watts
= 5000 kilowatts (standard scale)

PT = 7200:120 volts or 60:1 ratio
CT = 400:5 amps or 80:1 ratio
Wattmeter Catalog Number = 2830-1221-SCNWUJ2

Finally, each transducer has a range of calibration wattages over which the transducer can be adjusted to give 1.0 mA output. Provided that the desired F.S. wattage divided by the product of the PT and CT ratios is within this range, the transducer can be calibrated. (Note: All calibration of transducers is actually performed with single phase voltage and current, even for 3φ transducers. Since there is a fixed mathematical relationship between the 3φ performance and the 1φ performance, which is taken into account during calibration, this is permissible. This value of 1φ power used is known as the "calibration watts" or "FSW." Specifically, this is calculated as follows:

EQUATION : I Full Scale or Calibration $1\phi \text{ Watts} = \frac{\text{SCALE WATTS}}{\text{CT} \times \text{PT} \times \text{K}}$	1φ2W V_S = 7200 V (a)	3φ3W V_S = 7200 V (a)	3φ4W V_S = 7200 V V_{L-N} = 4160 V (b)
where K = 1 for 1φ2W 2 for 3φ3W 4 for 3φ4W	I = 400A PT = 60:1 CT = 80:1	I = 400A PT = 60:1 CT = 80:1	I = 400A PT = 35:5 CT = 80:1
Calculated watts	2,880,000	4,988,306	4,992,000
Standard Scale watts	2,500KW	5000KW	5000KW
Calibration watts/element (c)	520.8 watts	520.8 watts	446.4 watts

(a) VT is 7200:120 volt for use line to line (V_S).
(b) VT is 4200:120 volt for use line to neutral (V_{L-N}).
(c) 1Φ calibration watts (vars) range is 275-825 for all Watt and Var transducers.

When Ordering Wattmeters or Varmeters, Please Give the Complete 15 Digit Catalog Number, or Provide the Following Information:

1. Electrical system — 1φ2W, 3φ3W, 3φ4W.
2. System voltage (V_S). In the case of 3φ4W, state whether voltage is line to line (V_S) or line to neutral (V_{L-N}).
2.1. Potential transformer ratio (PT).
3. Line current (I).
3.1. Current transformer ratio (CT).
4. Desired scale range.
4.1. If specified be sure that range is within limits given by tables or calculated from **EQUATION I.**
4.2. If desired range is not specified, the nominal range from tables will be supplied.

POWER MEASURMENT

Calibration of these devices can be confusing. A **potential transformer** must be used for voltage over 600V. A **current transformer** must be used for currents over 10 Amps.

Calibration is the means to provide a ratio of primary to secondary power. These transformers provide that ratio with great accuracy

The calibration of meters and transducers is slightly different, in that, a meter has a definite scale in power which dictates the calibration based on scale, CT and PT ratios.

A transducer when used to power a meter must also be calibrated as if it were a meter since the meter scale sets calibration.

When a transducer is used to provide signal to a DCS or other data gathering system, a different set of rules apply.

Since most switchgear manufactures don't know what the transducer output will be used for, then standard calibration rules apply. Industry standard is 1500 watts for 4 wire and 1000 watts for 3 wire. This is helpful in that the same transducer may be used for all CT/PT combinations.

Use the example that you have 10 feeders on a motor control center. All are different horse power so all have different CT ratios. Lets assume these are 480V and the system is three phase, three wire. All transducers are calibrated at 1000 watts. To plug in numbers to DCS system, each circuit must be calibrated as follows:

> Motor #1 200HP-240FLA. - 300:5 CT 480:120PT (300/5=60:1), (480/120=4:1), 4x60=240 turns ratio. This is the ratio of primary to secondary power. We have a known value of 1000W and a ratio of 240:1 240x1000=240 Kilowatts. Output of transducer is 4-20MA so 4=0, 20=240KW. Continue same set of rules for other 9 moror circuits.

A watt meter can be calibrated about 30 percent above and below the calculated value. The chart on page 12 of the switchboard catalog shows these values Min - Max. Sometimes, a customer knows he will always be running a light load and would like better resolution on scale. So he would choose Min scale. Same is true for full load being always near Max.

Now that we understand watts, lets confuse the issue and discuss **VARS.**

"Volt amps reactive" The term VAR was coined in 1930 by the IEC in Stockholm. 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"

The common term for vars now are, IN or OUT. A varmeter is calibrated the same as a watt meter. Usually, the var scale is less than the watt scale because if you had all vars, this would be a useless system. The exception in calibration is that the phase angle must have current lagging or leading the voltage by 90degrees in which there are all vars and no watts. This results in a right hand deflection. A center zero meter will be in on left and out on right. There is no way to tell if this is lagging or leading.