Valhalla Scientific, Inc.

MODEL 3030A
POLYPOWER
ENERGY ANALYZER DATALOGGER

OPERATION MANUAL

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Introducing PolyPower

Congratulations on your decision to buy PolyPower! You have just purchased the smallest, most cost effective instrument for measuring and analyzing electric power that exists.

PolyPower is four instruments in one:
        a data logger
        a demand analyzer
        a harmonics analyzer
        a disturbance analyzer.

The philosophy of the product is to give you an instrument that answers just about all of your questions about electric power in a truly convenient size at an attractive price. With the addition of options, like the PC Control/Analysis Software, the capabilities just multiply.

Whether your interest is in measuring:
        true power
        actual cost
        harmonics
        transients
or any of 100 basic and advanced measurements of three phase and single phase circuits, **you've found your tool of first choice**.

Whether your interest is in:
        present values of variables
        maximum, minimum, and average values
        the complete data log of what's occurred
        or viewing actual waveforms (with the PC control/Analysis Software)

PolyPower puts all the power in the palm of your hand!

In a Hurry? --- Three Basic Rules of Operation

If you're in a hurry and have good sense, these three rules of operation will probably be enough to get you going:

1.   . Review the chapter on Connecting to PolyPower, paying special attention to the safety warnings. You or the unit can be damaged if you don't do things right!

2.   . Repeatedly press the button that's closest in meaning to the measurement you want until what you want is displayed. For instance, if you want a reading of the current in Phase C, press [Current] repeatedly until the measurement for I_c appears.

3.   . If the measurement that is displayed is close to what you want, but not quite what you're after, press [More...] repeatedly. For instance, if you want to know the average apparent power, press [Power] until apparent power is displayed, then [More...] until average apparent power appears.

These rules will safely provide you with a hundred different measurements.

Note: Throughout this manual, whenever we refer to an individual key of the keypad, we print the name on the key enclosed by square brackets. For example, the Volt key is referred to as [Volt].

Connecting to PolyPower

Voltage Test Leads

Each lead is uniquely labeled at both ends. They are identified as the V_a, V_b, V_c, and V_n test leads. The Deluxe Voltage Lead set is equipped with excellent plunger type jaws that may be actuated from three inches away from the actual metallic contact.

A word of caution: **Whenever connecting to a live circuit, remember that the open jaws of a voltage test lead are much wider than when they are closed. The potential to short two adjacent terminals or wires is a constant danger when connecting to a live circuit. Depending on the current capacity of the circuit being shorted, a deadly explosion of molten material can result!**

Once they are securely connected, the deluxe voltage leads are safe for steady voltages of the 600 Vrms rating of PolyPower.

Current Probes

Only probes supplied by Valhalla Scientific can be connected to PolyPower.

Probes such as the HA-1000 are excellent choices to use with PolyPower because they support all the specifications of the product. For instance, the HA-1000 has an accuracy of 0.5% whereas most probes on the market have an accuracy of 2-3%. Also, the HA-1000 maintains its accuracy for frequencies up to 20,000 Hz. This allows accurate current and power readings of distorted waveforms, accurate readings of harmonics, and the measurement of current transients that other probes would not even detect.

Phase shift is also an important probe characteristic. The HA-1000 has less than 2 degree of phase shift across the frequency range when measuring currents above 50 amps and just 1.5 degrees at 5 amps. This means that instantaneous measurements of power are highly accurate, regardless of the waveform. Most other probes on the market have much worse phase shift characteristics. This results in erroneous power and cost measurements and distorted waveforms. Please Note: To diminish phase shift when measuring small currents, it is advisable to clamp onto multiple "turns" of the same conductor in order to increase the effective current being sensed.

The HA-10 offers two advantages over the HA-1000, but these advantages come at a cost. Its advantages are that the HA-10 is a very small size and second, it offers much greater sensitivity since it reads currents from 30 milliamps to 10 amps (as compared to the HA-1000 measuring 1 - 1,000 amps). The tradeoff is accuracy. The probe has a basic accuracy of 2% and its phase shift varies by frequency and by amplitude. All told, you can expect to measure current to a nominal 3% accuracy and power and cost to a nominal 6% accuracy using the HA-10 probe.

The HA-150 probe is the same compact size as the HA-10. The HA-150 measures from 1 to 150 amps at 1% accuracy. It is a good choice over the HA-1000 if you wish to lock PolyPower, its leads, and current probes inside a power panel that you are monitoring. It is also a good choice when small size is important but currents are above 10 amps. These are a popular choice for a second set of probes.

The HA-100 probe measures from 0.1 to 100 amps. It's advantage over the HA-150 is its increased resolution in measuring small currents, but it is less accurate (2%).

For very large currents and large bus bars, we offer the HA-3000. This probe is capable of clamping onto cables of up to 2 1/2 inches wide and bus bars of 1.97x5.31 inches or 2.56x3.94 inches. It offers linearity of +/- 0.5 % +/- 1.5 amps from 150 to 3000 amps.

Connections to PolyPower

Voltage test leads plug into the back end of PolyPower. Each test lead is labeled (V_n, V_a, V_b, or V_c) and each jack is similarly labeled (V_n, V_a, V_b, or V_c).

Note: The V_n test lead is a different color from the other leads. Similarly, the V_n jack on PolyPower is a different color from the other ones. Connecting anything other than neutral or ground to the V_n jack can jeopardize your safety, the functioning of the unit, and the accuracy of the unit.

Current probes plug into the sides of PolyPower. Each current probe is labeled (I_a, I_b, I_c, or I_n) and each jack is similarly labeled (I_a, I_b, I_c, or I_n). The I_a and I_n probes plug into the left side of the unit. The I_b and I_c probes plug into the right side of the unit. When plugging a current probe into PolyPower, line up the point of the arrow on the plug to the point of the arrow on the PolyPower case before pushing the plug in.

Connecting to Single Phase Power

Figure 1 presents the basic connections to a single phase system. **Be sure to follow the safety warnings of the previous sections before making the connections.**

Clamp your A phase current probe onto the "Hot" wire. Make a metallic connection to neutral with the V_n voltage lead. Similarly connect the V_a lead to "Hot". Connect V_n to the Neutral. Since voltage now comes into PolyPower on V_a and current is sensed by I_a, the power and power factor for this single phase system will be available as phase A power and phase A power factor.

Fig. 1 - Basic Single Phase Connection

Fig 2 shows the complete connections to a single phase system as found in commercial and residential facilities. There are two "Hot" wires out of phase with each other and sharing the same "Neutral". Appliances such as ovens that require 220V will span across both "Hot" wires.

In this configuration, a reading of V_{an} is of "Hot"-to-"Neutral", V_{bn} is "Ground"-to-"Neutral", and V_{cn} is "Hot2"-to-"Neutral". The power associated with one "Hot" is measured as phase A, the power of the other "Hot" is measured as phase B. In phase- to-neutral measurement mode, the voltage readings will be from "Hot" to "Neutral". If you change the measurement mode to phase-to-phase, V_{ab} will be the "Hot"-to-"Hot" voltage that the high power appliance is operating on.
Caution: Until you are certain that your voltage connections to PolyPower are correct, disconnect any current probes. This is because PolyPower and all of its connections float at the potential of V_n. If V_n is "Hot", there may be a breakdown through the insulation of any attached probes.

Fig.2 - Complete Single Phase Connection

Helpful Hint: How to Identify the "Neutral" lead.
Normal single phase wiring follows the convention of "Neutral" being the white wire, "Hot" being the black wire, "Hot2" being the red wire, and "Ground" being the green wire. If the wiring and your connections to PolyPower are correct, V_{an} will be some relatively large number like 120 volts and V_{bn} will be a small voltage like 3 volts. If you then reverse the ground and neutral leads, V_{an} will now read slightly less, like 117 volts. If "Hot" and "Neutral" are reversed,
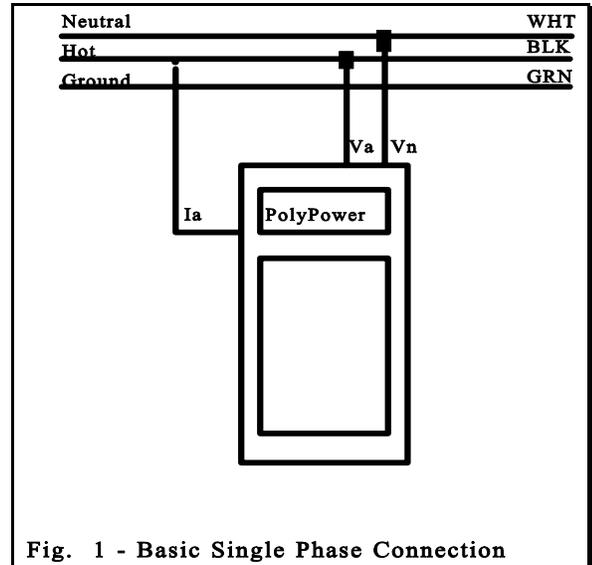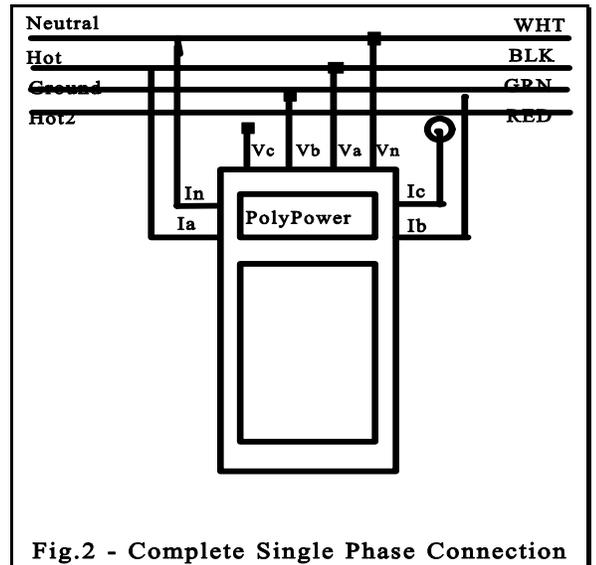
then V_{bn} will become a large number, like 117 volts.

Connecting to 120 Vac Line Adapter Box

The 120 V Line Adapter Box accessory offers a safe, convenient, and accurate way to monitor voltage in a commercial setting or to evaluate power usage of appliances.

Figure 3 presents the connections to the Adapter Box. Simply plug the adapter box into a wall socket and then attach the voltage and current leads into PolyPower. Each lead is labeled to eliminate misconnections.
Note: The V_a lead must not be connected to V_n. If the I_a lead is connected, a short circuit will result that will quickly disable PolyPower. Also, make sure that the hot and neutral wiring being measured is not reversed. If so, PolyPower and its attachments will "float" at 120 V.

To evaluate the power usage of an appliance, simply plug the appliance into the top of the 120 Vac Line Adapter Box after the other connections have been made and verified. Even without an appliance plugged in, the adapter box offers a convenient means of checking for transients or analyzing the harmonic content of the incoming voltage.

Fig. 3 - Connecting To The 120V Line Adapter

Connecting to Multiple Single Phase Loads

Figure 4 presents a means to monitor 3 single phase loads simultaneously. The loads must all share the same neutral voltage connection. If the loads run off the same line voltage, connect V_a, V_b, and V_c to the same "Hot" wire. I_a, I_b, and I_c serve the 3 loads. I_n can also be used to evaluate the current of a 4th load, but the power used by that load will not be available.

In this configuration, each voltage and current can be displayed directly, however PolyPower will display only the total power of the 3 loads. There is a way to determine the power in each load. If PolyPower is linked to a computer equipped with the PC Control/Analysis Software, the three individual power components can be retrieved, analyzed, and graphed on the PC.
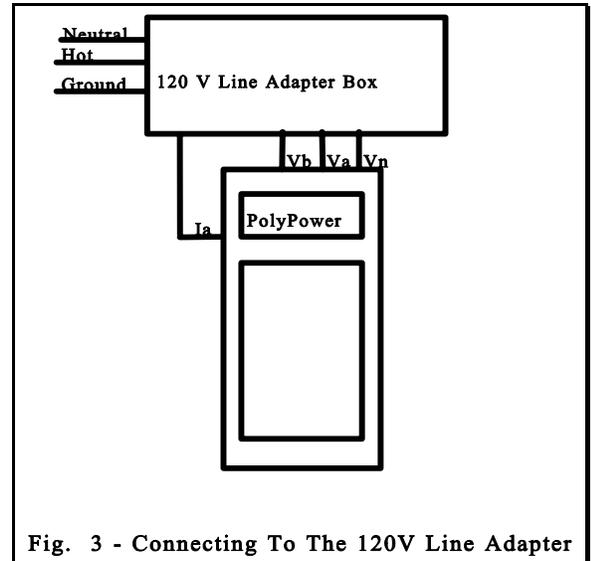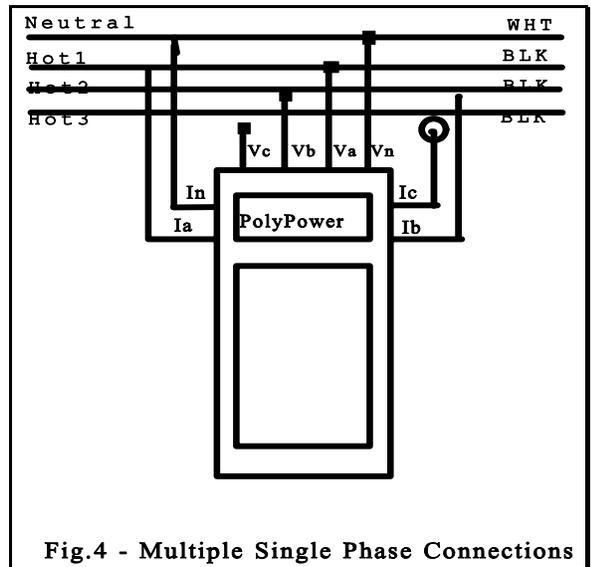

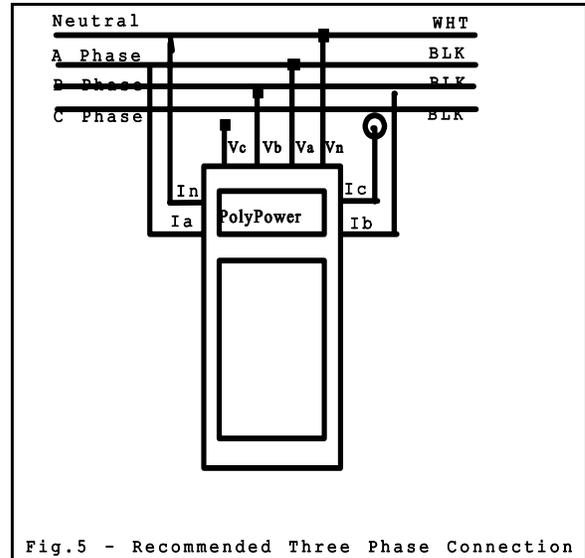Fig.4 - Multiple Single Phase Connections

Connecting to Three Phase Phase-to-Neutral (Wye) Power

Figure 5 presents the recommended connections to a three phase system with voltages referenced to neutral, a "wye" or "phase-to-neutral" configuration. **Be sure to follow the safety warnings of the previous sections before making the connections**.

Although the current of each phase is carried by neutral, neutral current is generally relatively small since the currents of the 3 phases largely cancel each other in the neutral leg. In a perfectly balanced system the current in neutral would be zero.

In a wye system, each phase is essentially independent of each other. For this reason, the power factor of each phase has direct meaning, but the total power factor is less meaningful.

Fig.5 - Recommended Three Phase Connection

Most commercial wiring and newer industrial wiring is in this wye configuration.

Connecting to Three Phase Phase-to-Phase (Delta) Power

Figure 6 presents the recommended connections to a three phase system with voltages referenced to each other, a "delta" or "phase-to-phase" configuration. **Be sure to follow the safety warnings of the previous sections before making the connections.**
Please Note: Do not connect the V_n input to anything when measuring in phase-to-phase measurement mode. This may affect the accuracy of the measurements.

In a delta configuration, current flowing in each phase is due to the interaction of 2 different voltages. For instance I_a current is the resultant of V_{ab} and V_{ca}. There is no way to determine what portion of the current is due to which voltage. Also the concept of power factor is quite different from that in a wye circuit. You would not expect to achieve a power factor of 1.00 even if the load were purely resistive. For this reason, only the total power and total power factor has real meaning in a delta system. Delta power is common in large motors and older

Fig. 6 - Recommended Three Phase (Delta) Connection

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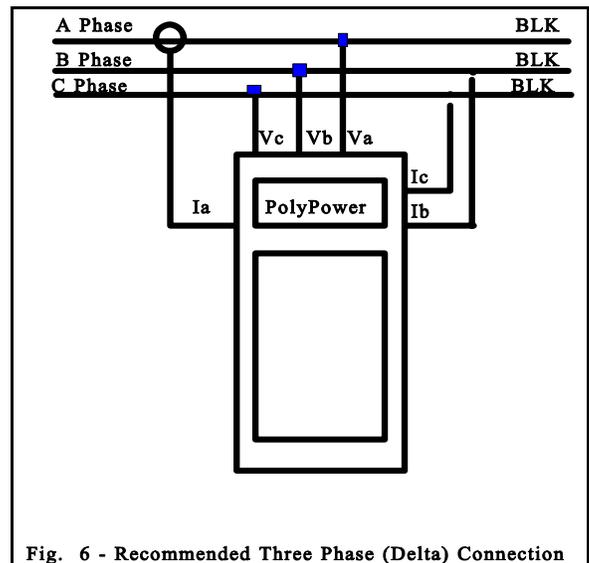
industrial sites.

Turning PolyPower On

Connecting to Power

PolyPower is supplied with a wall mount power supply. Simply plug the power supply into any 120 Vac source and then plug its pigtail into the 12 V_{DC} input jack on the back end of PolyPower.

If you wish to operate PolyPower without being tethered to a power outlet, the NEMA Box accessory offers the ability to power PolyPower directly off the line voltage being monitored. This is especially convenient when monitoring in areas where 120 Vac outlets are not readily available.

Although PolyPower comes with rechargeable batteries, those batteries are intended to keep PolyPower going during brief power failures and to allow quick measurements without the bother of always having to find a 120 Vac source. These internal batteries are automatically trickle charged when the wall mount supply is connected to the unit (or when PolyPower is mounted within the NEMA box accessory). When fully charged, the batteries can power the unit for up to 10 hours.

Turning PolyPower On

Simply press the red push-button switch on the front panel and you're in operation (pressing the button again, turns the unit off). The initial greeting immediately comes on the screen. You can change this greeting at any time by following the directions in the administrative functions that are accessed by pressing the [Administrative] key. Please note that turning PolyPower on does not automatically start the monitoring or data logging functions. See applicable sections.

Measurements

Voltage Measurements

PolyPower performs most desired voltage measurements. When in "Phase-to-Neutral" measurement mode, the RMS (root mean square) voltage between V_n and the V_a, V_b, and V_c jacks is available by simply pressing [Volt] repeatedly. The sequence of the display is $V_{an} > V_{bn} > V_{cn}$. In the "Phase-to-Phase" measurement mode, V_{ab}, V_{bc}, and V_{ca} are available instead. If energy consumption is being monitored, the maximum, minimum, and average RMS voltage is displayed by repeatedly pressing [More...] after displaying the appropriate present voltage. In this way, by combining the [Volt] and [More...] keys, there are 12 RMS voltage measurements available.

For instance, if the average voltage between V_b and V_n is desired, press: [Volt] (to display)V_{an}, [Volt] (to display V_{bn}), [More...] (to display maximum V_{bn}), [More...] (to display minimum V_{bn}), and then [More...] (to display average V_{bn}). Note that if PolyPower is not monitoring consumption, the maximum, minimum, and average values are the results from the last monitoring session.
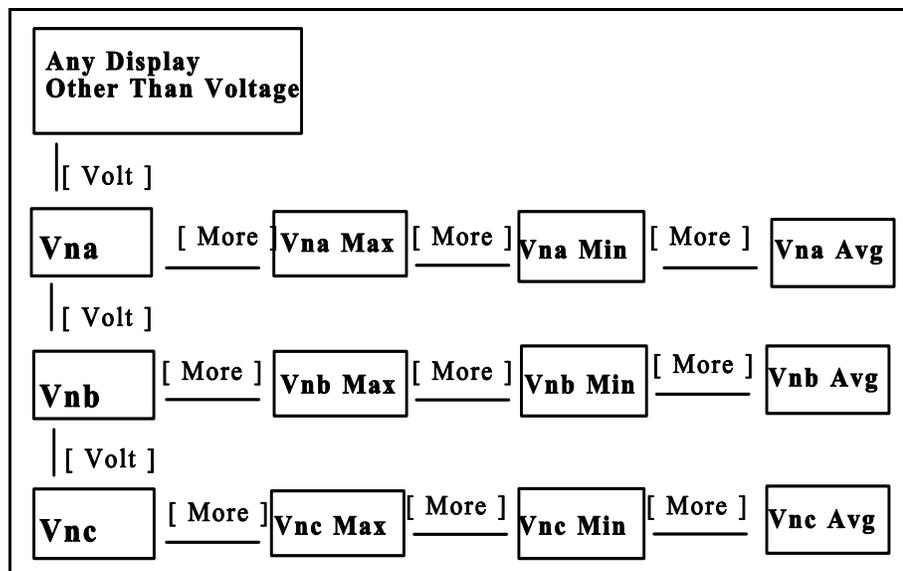
RMS voltage is defined as the square root of the mean of the square of the instantaneous voltage over one cycle of the fundamental frequency.

Crest factor is another measurement of voltage. It is the ratio of the peak voltage to the RMS voltage. Crest factors are displayed for waveforms uploaded into the PolyPower Manager (PSM) program. The total harmonic distortion of voltages are displayed using the THD function.

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Current Measurements

PolyPower performs most desired measurements of current . The RMS (root mean square) currents of the A, B, and C Phases and of the Neutral Line are available by simply pressing [Current] repeatedly. The sequence of the display is $I_a > I_b > I_c > I_n$. If energy consumption is being monitored, the maximum, minimum, and average RMS current is displayed by repeatedly pressing [More...] after displaying the appropriate present current. In this way, by combining the [Current] and [More...] keys, there are 16 RMS current measurements available.

| Ia | [More] | Ia max | [More] | Ia min | [More] | Ia avg |
| [Curr] |
| Ib | [More] | Ib max | [More] | Ib min | [More] | Ib avg |
| [Curr] |
| Ic | [More] | Ic max | [More] | Ic min | [More] | Ic avg |
| [Curr] |
| Id | [More] | In max | [More] | In min | [More] | In avg |

Fig. 8 - User Interface For Current Measurements

For instance, if the average current of the C Phase is desired, press: [Current] (to display I_a), [Current] (to display I_b), [Current] (to display I_c), [More...] (to display maximum I_c), [More...] (to display minimum I_c), and then [More...] (to display average I_c).

Note that if PolyPower is not monitoring consumption, the maximum, minimum, and average values are the results from the last monitoring session.
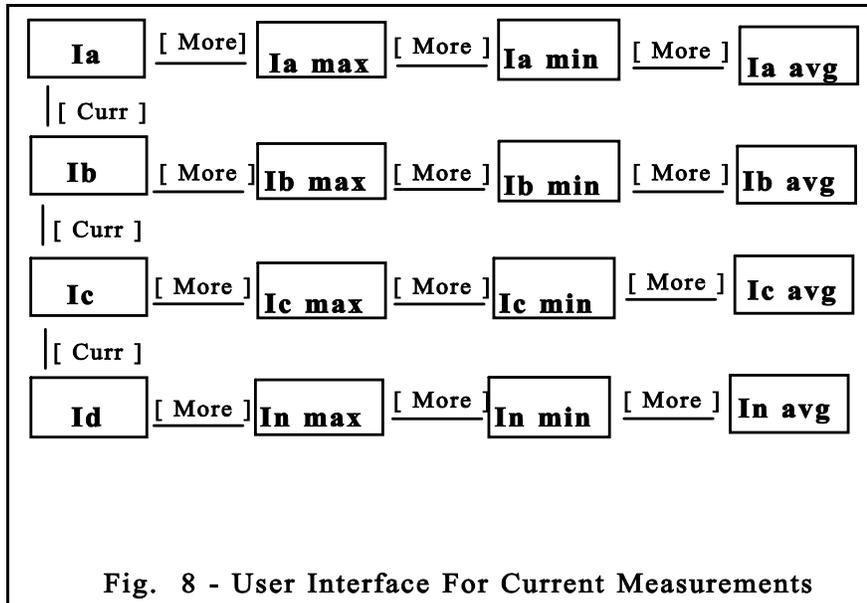
RMS current is defined as the square root of the mean of the square of the instantaneous current over one cycle of the fundamental frequency:

$$I_{rms} = \sqrt{\frac{\int I^2}{n}}$$

Crest factor is another measurement of current. It is the ratio of the peak current to the RMS

current. Crest factor readings are available for waveforms uploaded into the PolyPower Manager program. The total harmonic distortion of currents are displayed on PolyPower using the THD function.   K factor, another distortion measurement for current, is available for waveforms uploaded into the PolyPower Manager program.

Power Measurements

PolyPower performs most desired power measurements. True power and apparent power (VA power) measurements are available by simply pressing [Power] repeatedly. The sequence of the display is $P_{true} > P_{app}$. If energy consumption is being monitored, the maximum, minimum, and average power is displayed by repeatedly pressing [More...] after displaying the appropriate power type.   In this way, by combining the [Power] and [More...] keys, there are 8 power measurements available.

Fig. 9 - User Interface For Power Measurements
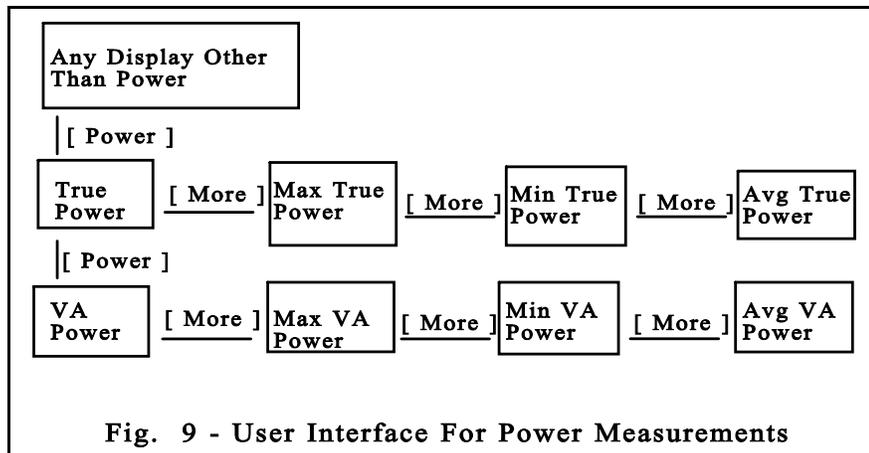
For instance, if the maximum apparent power is desired, press: [Power] (to display P_{true}), [Power] (to display P_{app}), and then [More...] (to display maximum apparent power).

Apparent power is defined as the sum of the products of the RMS currents and their associated RMS voltages:

$$P_{app} = (Van_{rms} \times Ia_{rms}) + (Vbn_{rms} \times Ib_{rms}) + (Vcn_{rms} \times Ic_{rms})$$

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Unless the load is purely resistive, the apparent power will overstate the actual power consumed. True power is defined as the sum of the products of the instantaneous currents and their associated instantaneous voltages:

$$P_{true} = \left(\int V_{an} \times I_a \right) + \left(\int V_{bn} \times I_b \right) + \left(\int V_{cn} \times I_c \right)$$

Power Factor Measurements

PolyPower performs many desired power factor measurements . The true power factors of the A, B, and C Phases and the total power factor of the three phases are available by simply pressing [Power Factor] repeatedly. The sequence of the display is PF_a > PF_b > PF_c>PF_t. If energy consumption is being monitored, the maximum, minimum, and average power factor are displayed by repeatedly pressing [More...] after displaying the appropriate power factor.

Fig. 10 - User Interface For Power Factor Measurements
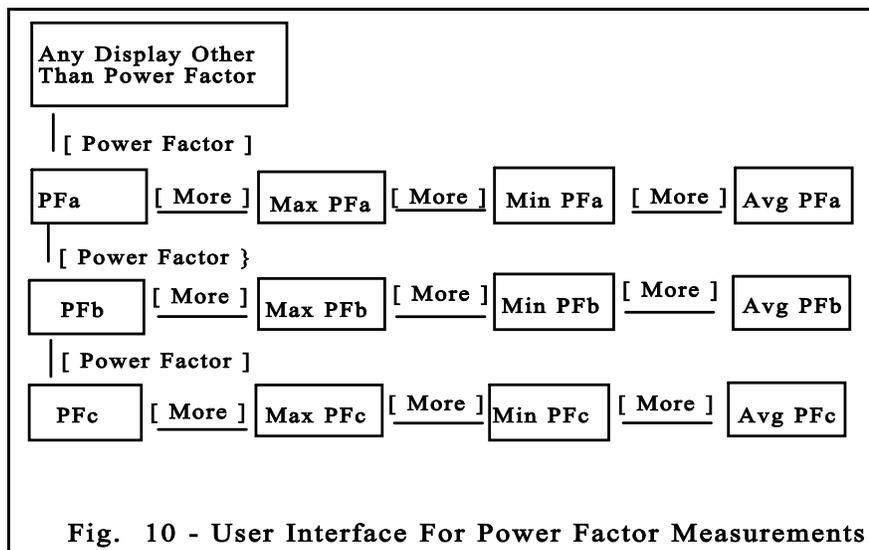
For instance, if the average power factor of the C Phase is desired, press: [Power Factor] (to display PF_a), [Power Factor] (to display PF_b), [Power Factor] (to display PF_c), [More...] (to display maximum PF_c), [More...] (to display minimum PF_c), and then [More...] (to display average PF_c).

In this way, by combining the [Power Factor] and [More...] keys, there are 16 power factor measurements available.

The display of power factor tells you if current is leading or lagging voltage. For instance, if current lags voltage in phase A, the display will read "(Van,Ia)". If current leads voltage, the display reverses the order and reads "(Ia,Van)". Determining whether current is leading or lagging is necessary when correcting power factor by using capacitance. Of course, by uploading the voltage and current waveforms, the lead/lag relationship may be viewed directly. True power factor is defined as the ratio of the true power to the apparent power:

Power factor is 1.00 for a purely resistive load and drops down as the reactive power or harmonic content increases.

Displacement power factor is related to the phase lag between the fundamental frequencies of the voltage and current. When the harmonic content of voltages and currents is low, the true power factor is equivalent to the displacement power factor.

Energy Measurements

PolyPower performs most desired energy measurements. When monitoring consumption, the actual energy consumed is displayed by pressing [Energy]. Based on the history of consumption, estimates of energy use per hour, energy use per month, and energy use per year are calculated each second. These estimates are available by repeatedly pressing [More...]. In this way, by combining the [Energy] and [More...] keys, there are 4 energy measurements available.

For instance, if the estimated energy use per year is desired, press: [Energy] (to display total energy consumed), [More...] (to display kw-hr / hour), [More...] (to display kw-hr / month), and then [More...] (to display kw-hr / year).

Energy consumed is defined as the sum of the true power over time:

Cost Measurements
PolyPower performs most desired true cost of energy measurements. When monitoring consumption, the actual cost of energy consumed is displayed by pressing [Cost]. Based on the history of consumption, estimates of the cost per hour, the cost per month, and the cost per year are calculated each second. These estimates are available by repeatedly pressing [More...] after displaying the cost measure.

For instance, if the estimated cost per year is desired, press: [Cost] (to display total cost incurred during monitoring), [More...] (to display $ / hour), [More...] (to display $ / month), and then [More...] (to display $ / year).

In this way, by combining the [Cost] and [More...] keys, there are 4 cost measurements available. The cost of energy consumed is defined as the product of the energy consumed times the user-defined rate:

Install Equation Editor and double-

Demand Period Measurement

During monitoring of energy consumption, the peak demand period is constantly updated. The peak demand period is the period of time during which the most true power was consumed. The first demand time interval starts when monitoring begins and lasts for the number of minutes set by the user (the "logging period", set as an administrative function). The unit comes from the factory with the logging period set to 15 minutes. Hence a new unit that starts monitoring at 7:00 A.M. will update the demand period at 7:15, 7:30, 7:45, 8:00, and so on. If the most power was consumed between 7:45 and 8:00, then the demand period will be displayed as 7:45. Note that even if the power peaked briefly at 7:29, the demand period would still be reported as 7:45 since more power was consumed over that 15 minute period.

To see what the demand was during the peak demand period, press [Demand] (to see the time and date of the peak demand period) and then [More…]. (to see the amount of energy consumed during that period).

Frequency Measurements

PolyPower performs most desired frequency measurements. The fundamental frequency is displayed by pressing [Freq]. If consumption is being monitored, the maximum, minimum, and average frequency is displayed by repeatedly pressing [More…] after displaying the frequency.

For instance, if the minimum frequency since monitoring began is desired, press: [Freq] (to display fundamental frequency), [More…] (to display maximum frequency), and then [More…] (to display minimum frequency).

PolyPower scans its inputs each second to look for an active power signal to measure. If none is detected, all voltage and current measurements are assumed to be zero for that second. This scanning feature allows the user to connect and disconnect PolyPower to various signals without being concerned with the source of the frequency measurement.

It is important to monitor frequency at installations that generate their own power. Measuring frequency each second is also important to assure the accuracy of all other measurements. If an instrument makes the wrong assumption about the fundamental frequency, all voltages, currents, powers, etc. will be inaccurate.

Duty Cycle Measurements

PolyPower performs most desired duty cycle measurements. If consumption is being monitored, the per cent of the time that current is flowing in the A phase is displayed by pressing [On/Off Cycles]. The average "on" time and the average "off" time are displayed by repeatedly pressing [More…].

For instance, if you are monitoring a refrigeration unit, press [On/Off Cycles] to display how much of the time the compressor is running and then press [More…] to display how long the compressor runs on average.

The level of current considered to be "on" may be easily set by the user. It is a function accessed through the [Administration] key. Using this feature, a user could define 2 amps as "on" (and hence anything less than 2 amps as "off"). This would allow minor currents to flow in a circuit without affecting the duty cycle measurement. The unit comes from the factory with the "on" current set to 1 amp.

Power Cycle Measurements

PolyPower performs most desired power cycle measurements. If consumption is being monitored, the number of times that current in the A phase goes "on" is displayed by pressing [On/Off Cycles] once or twice. Based on the history of monitoring consumption, estimates of the rate of on/off cycles are calculated each second. These estimates are available by repeatedly pressing [More...] after displaying the total number of power cycles.

For instance, if you are monitoring an air conditioning system and wish to know how many times per hour the unit turns on and off, press: [On/Off Cycles] until the number of power cycles during monitoring is displayed and then [More...] to display power cycles per hour.

As mentioned in the previous section, the "on" current used for measuring on/off cycles can be set by the user. It is a function accessed through the [Administration] key.

Time Measurements

PolyPower performs most desired time measurements. Pressing [Time] yields the present time in 24 hour format. When monitoring consumption, pressing [Time] again displays the elapsed time since monitoring of consumption began.

The time and date that monitoring began can be obtained by pressing [Time] (to see the present time), [Time] (to see the elapsed time) and [More...] (to see the time and date that monitoring began).

In this way, the [Time] key provides 3 time measurements.

The time (and date) may be easily changed by the user. It is a function accessed through the [Administration] key.

Measuring Harmonic Distortion
PolyPower performs most desired measurements of harmonic distortion. The total harmonic distortion (THD) of any voltage or current can be calculated and displayed upon demand by simply pressing [Harmon Distor] and then [Yes/Accept] or [No/Reject] in response to the displayed questions. The sequence of the questions is "calculate THD of I_a?" > I_b? > I_c? > I_n? > V_{an}? > V_{bn}? > V_{cn}?. When the calculation is completed, the result is reported as a percent. If the Harmonic Analysis Option is loaded on the unit, the relative magnitude of each harmonic frequency is displayed by repeatedly pressing [More...].

For instance, if the THD of I~b~ is desired, press: [Harmon Distor] whereupon it asks to calculate THD on I~a~, [No/Reject] (to reject calculating THD of I~a~), and [Yes/Accept] (to calculate and display the THD of I~b~). If the Harmonic Analysis Option is loaded, pressing [More...] three times will display the relative harmonic amplitude of the third harmonic of I~b~.

The Harmonic Analysis Option allows displaying individual harmonics through the 15th on the unit. By combining this option with the PC Control/Analysis Option, individual harmonics through the 50th can be measured and graphed on the computer.

In this way, the [Harmon Distor] key controls 7 harmonic distortion measurements. If the Harmonic Analysis Option is loaded, 105 harmonic measurements are available on the PolyPower display.

It must be noted that harmonic distortion measurements are so computationally demanding that PolyPower stops monitoring energy consumption in order to perform the calculations. For this reason, if the user presses [Harmon Distor] while monitoring consumption, the unit will insist that the user end monitoring of consumption before the calculations begin.

Total harmonic distortion is defined as the square root of the sum of the squares of the magnitude of each harmonic of the fundamental frequency divided by the square of the magnitude of the fundamental frequency:

$$THD = \frac{\sqrt{H_2^2 + H_3^2 + \cdots H_{50}^2}}{H_1^2}$$

For instance, if you are monitoring a 60 Hz voltage that has minimal distortion, H_1 (the magnitude of the 60 Hz fundamental) might be 120, H_3 (the magnitude of the third harmonic, 180 Hz) might be 2, and all the other harmonics might have magnitudes of 0.
In this case, The magnitude of the third harmonic would be reported as 0.02 (relative to a fundamental magnitude of 1.00).

$$THD = \sqrt{\frac{2^2}{120^2}} = 2\%$$

A related measurement is K factor. K factor measurements are available on the PC if the PC Control/Analysis Option and Harmonic Analysis Options are present.

Monitoring Energy Consumption

When PolyPower is first turned on, it operates like a reporter, describing what it sees. New measurements are generated each second that replace old measurements. Old measurements are

discarded. When you direct PolyPower to begin monitoring consumption, it not only reports what it sees, it also generates summary information each second. Summary information includes:

- maximum values since monitoring began
- minimum values since monitoring began
- average values since monitoring began
- totals since monitoring began.

These summary statistics are of great value to you as you ask questions such as: "What is the minimum voltage?" "What is the maximum current?" "How much does it cost to run?" "What is the average load?" "When is my demand period?".

When you tell PolyPower to stop monitoring, these summary measurements remain available to you. To make sure that you don't assume that they are still being updated, PolyPower flashes the warning "-Not Monitoring-" when you view measurements that are no longer being updated.

To start monitoring, press the [Monitoring On/Off] key and follow the directions that are displayed. For instance, to start consumption monitoring after turning PolyPower on, first press [Monitoring On/Off] and it asks if you wish to" begin monitoring of consumption". Press [Yes/Accept] and monitoring begins. You are flagged that monitoring is in progress by the flashing asterisks, "*", that appear on both ends of the bottom line of the display.

To stop monitoring, press the [Monitoring On/Off] key and follow the directions that are displayed. Typically you would press [Monitoring On/Off] and it would ask if you wish to stop monitoring of energy consumption. Press [Yes/Accept] and consumption monitoring immediately ends. You are assured that monitoring has ended by the absence of the flashing asterisks, "*", that appeared on both ends of the bottom line of the display and by the "-Not Monitoring-" warning that flashes when looking at summary measurements.

Logging Energy Consumption

The basic PolyPower unit monitors energy consumption as described in the previous section. When the Data Logging Option is installed in your unit, a large amount of additional data is obtained. With data logging, the maximum, minimum, and average values of many variables are calculated and stored during regular time intervals.   The time frame over which these readings are regularly calculated is called the logging period.

One record of measurements is created and stored in PolyPower at the end of each logging period. Thus if the logging period is set to 15 minutes and you monitor a circuit for 1 hour, 4 data log records will have been created and stored (one each 15 minutes). Each of the records would contain summary information for 900 seconds (15 minutes) of measurements (saving the maximum, the minimum, and the average values of each of the variables for that 900 seconds). You can set the logging period to any length of time from 1 second to 99 minutes (it comes from the factory set to 15 minutes).

Each record consists of 59 variables. They include the maximum, the minimum, and the average of the following variables:

- voltage from neutral to A phase (phase-neutral mode)
- voltage from neutral to B phase (phase-neutral mode)
- voltage from neutral to C phase (phase-neutral mode)
- voltage from A phase to B phase (phase-phase mode)
- voltage from B phase to C phase (phase-phase mode)
- voltage from C phase to A phase (phase-phase mode)
- current in A phase
- current in B phase
- current in C phase
- current in neutral
- true power in A phase
- true power in B phase
- true power in C phase
- VA power in A phase
- VA power in B phase
- VA power in C phase
- true power factor of A phase
- true power factor of B phase
- true power factor of C phase
- fundamental frequency.

In addition, it contains the time and date of the logging period and optionally may contain a snapshot of the harmonic distortion in each of the voltages and currents (see the AutoTHD Feature).

The Data Logging Option permits the storage of 982 of these records. Thus if 15 minute logging periods are used, the data log will hold summary data for the last 10 days of energy consumption (15 minutes x 982). If 1 minute logging periods are used, the data log will hold the summary data for the last 16 hours of monitoring. If monitoring continues long enough to fill the data log, a new record is written over the oldest record of the log each logging period. In this way, you could leave a unit monitoring unattended for months and always have the most recent data available for analysis.

The contents of the data log cannot be displayed on PolyPower's display. To obtain the information, it must be uploaded from PolyPower to your computer using the PC Control/Analysis Software. The data is recorded into a file in a plain text format that may be easily imported into spreadsheets, databases, and word processors. In addition, the PC Control/Analysis software has extensive graphing and printing capabilities.

Only one data log exists within PolyPower at any given time. Thus when monitoring of consumption is proceeding, the data log is growing by one record each logging period. When monitoring is stopped, the data log no longer grows, but it is still available. The data is preserved even if the unit is turned on and off repeatedly. However, when monitoring is started

again, the old log is immediately erased to make room for the new log.

AutoTHD Feature

The autoTHD feature presents several benefits and compromises. When it is active and energy consumption is being monitored, a THD measurement is taken for all active inputs to PolyPower. Each THD measurement is a snapshot of the harmonic content of the signal at that time. It is included in the data log and may be graphed and printed using the PC Control/Analysis software. If an active signal is not present, its THD is recorded as 0 in the data log. If autoTHD is disabled, the THD of all signals is recorded as 0.

A limitation of autoTHD at this time is that while the calculations are being done, normal measurements are suspended. Hence, if a new maximum or minimum voltage or current occurs during the calculation time, it will not be recorded. Similarly, the measurements of total energy used and total cost will not be increased during that time. For these reasons, we disable the autoTHD feature when we ship a new unit. You may enable the feature (or disable it again) whenever you choose as one of the administrative functions.

Disturbance Monitoring

PolyPower can monitor for power disturbances. Common disturbances are transients, surges, and sags. During disturbance monitoring, PolyPower monitors for voltage or current transients that last at least 32 usec. During consumption monitoring, PolyPower is guaranteed to catch voltage and current sags and surges that last for 1 second (surges and sags of less than that duration may or may not be caught depending on timing).

A transient is a sudden rise in voltage or current that happens irregularly. During disturbance monitoring (or "spike monitoring") PolyPower devotes all its resources to looking for transients on the one voltage or current signal that you specify. Whenever it sees a magnitude above the level that you specify, the event is noted and, if it is the worst transient since monitoring began, its statistics are noted.

To begin monitoring disturbances, press the [Monitoring On/Off] key and follow the directions that are displayed. For instance, to start monitoring transients on V_{an}, first press [Monitoring On/Off] and it asks if you wish to begin monitoring of consumption. Press [No/Reject] and it asks if you wish to begin monitoring of disturbances. Press [Yes/Accept] and it asks if you wish to monitor V_{an}. Press [Yes/Accept] and it asks if you wish to set the transient threshold at a suggested value (the value is at least 10% above the peak value that PolyPower presently sees for that signal). Press [Yes/Accept] and disturbance monitoring begins. You are flagged that disturbance monitoring is in progress by the flashing exclamation marks, "!", that appear on both ends of the bottom line of the display and by the summary display of how many transients above the threshold have been encountered since monitoring began.

Since disturbance monitoring takes all of PolyPower's attention, any request you make causes it to suspend monitoring. For instance if you press [Volt] to check the present voltage level,

PolyPower immediately suspends monitoring to service that request and asks if it was OK to suspend monitoring. If you press Yes/Accept] then monitoring stays suspended. You are reminded of this fact by the exclamation marks remaining "on" permanently on the bottom display line. You can now obtain any measurement and perform most functions without limitation. If you had pressed [No/Reject], PolyPower would have immediately returned to disturbance monitoring and the exclamation marks would have resumed blinking.

While monitoring is suspended, pressing [Spike] causes the summary display to appear. This states how many transients exceeded the threshold that you set when monitoring began. Pressing [More...] repeatedly displays information about the worst transient that was detected. The worst transient is defined to be the one with the largest magnitude. Pressing [More...] the first time displays the peak magnitude of the worst transient. Pressing [More...] again displays the duration of the transient, in microseconds. Pressing [More...] again displays the rise time of the transient, in microseconds. Pressing [More...] one more time displays the time of day that the transient occurred. The date that it occurred flashes on the screen every few seconds.

When you wish to resume monitoring, press [Monitoring On/Off]. PolyPower will ask if you wish to resume monitoring. Press [Yes/Accept] and the disturbance summary is displayed and the exclamation marks resume flashing. Any new transients are added to the old total and are compared to the previous worst transient.

If you wish to end monitoring after it has been suspended, press [Monitoring On/Off] whereupon it asks if you wish to resume monitoring. Press [No/Reject] whereupon it asks if you wish to stop monitoring of disturbances. Press [Yes/Accept]. This causes the exclamation marks to disappear and allows a new disturbance summary to be created the next time you begin monitoring disturbances.

Other Functions

Setting the Measurement Mode

PolyPower has two modes of measurement: phase-to-neutral and phase-to-phase. When in phase-to-neutral, all voltage readings are for the voltage from the V_n terminal to one of the voltage phase inputs. They are displayed as V_{an}, V_{bn}, or V_{cn}. When in phase-to-phase measurement mode, all voltage readings are for voltages between the voltage phase inputs. They are displayed as V_{ab}, V_{bc}, or V_{ca}.

There are several important considerations in phase-to-phase measurement mode. First off, voltage disturbances can only be monitored from phase-to-neutral even in phase-to-phase mode. Next, the power factor and power reading of each phase are not strictly accurate. This is not due to any accuracy problem with PolyPower. Instead, it is the result of each phase's current being the result of two different phase-to-phase voltages. Although the power factor and power readings may have diagnostic value, they are not true representations of the actual power factor or power being used for a given phase. Nevertheless, the measurements that really count, the total power factor and total power, are correct in phase-to-phase mode. This result may seem surprising, given that the individual phase measurements are not exact, but combining the three readings with three unknowns eliminates the inaccuracy of the individual phase measurements.

To change the measurement mode, press [administrative]. When asked if you wish to change the measurement mode, press [yes/accept]. The present mode will be displayed. If you wish to change from that measurement mode, press [no/reject]. The other mode will now be displayed. Press [yes/accept] and you have chosen that mode.

The measurement mode will stay in effect until you change it. It is not changed by turning PolyPower off.

Setting Input Ratios

There are several occasions when you may choose to enter input ratios for measuring voltage and current. This most commonly occurs when monitoring a large main circuit to a facility. The current may be too large to measure with the current probes you own, or you may not be able to physically clamp around the cable or bus bar. In those instances a permanently installed CT may be wired in for a metering system. By clamping onto the secondary of such a CT (typically with an HA-10 probe), you obtain readings proportional to the primary side of the CT. Entering the ratio of the CT into PolyPower allows all recorded values to be scaled appropriately. PolyPower then records primary values, although it is connected to the secondary.

There are other instances where input ratios are valuable. If a large current is carried by 2 or more parallel conductors, you can clamp onto 1 conductor, enter in the ratio (for instance 4 total conductors to 1 measured conductor) and thereby record the total power without clamping around all the conductors. However, before you use this approach, verify that each conductor is

carrying the same amount of current. It's not uncommon for parallel conductors to carry different loads when high currents are involved. If the loads are different in each conductor, you may enter the appropriate input ratio. For instance, if 2 cables carry 2000 amps and the one you monitor carries 980 of the amps, you can enter the ratio 2000 : 980 and all readings will be correct.

There are cases where you may wish to measure very small currents with a large probe. In order to improve the accuracy of the readings, you may wish to clamp onto several turns of the wire. This essentially amplifies the signal and boosts the signal to noise ratio. For instance, if you were reading 1 amp with an HA-1000 probe, you might clamp onto 10 turns of the wire to boost the signal to 10 amps. If you then entered a ratio of 1 : 10, the readings will be scaled correctly and be more accurate.

Finally, in measuring high voltages, you may choose to monitor the output of a PT (potential transformer), enter the PT ratio and thereby record the primary values. Similarly, if you use a high voltage probe, enter the ratio of the probe (for instance, 100 : 1) and record the actual voltage being measured.

Using these techniques, you can measure anything with PolyPower. The measurement range extends from 1 milliamp to more than 4 million amps, 1 volt to more than 4,000 kilovolts, 1 watt to more than 40 megawatts!

As an example, suppose you wish to record the primary of a permanently installed CT while clamped onto the secondary with your I_a current probe. First press [Calibra]. When it asks if you wish to calibrate current, press [Yes/Accept]. When it asks if you wish to set the input ratio, press [Yes/Accept]. Assume that the ratio of the CT is 600 : 5. When it next asks you to enter the ratio, enter the source value ("600" in this case) using the keys with numbers on them and then [Yes/Accept]. The cursor then moves to the right side, the input side. Enter the input ("5" in this case) and then [Yes/Accept]. It next asks if the ratio ("600 : 5" in this case) is for I_a. Enter [Yes/Accept]. It next asks if the ratio applies to I_b, then I_c, then I_n. Answer yes or no as is appropriate.

Note: Once it is entered, an input ratio is kept for the specified inputs until you either change the ratio again or you turn the unit off. After turning PolyPower on, the input ratio for all inputs is automatically set to 1 : 1.

Saving Waveforms

PolyPower has the ability to store sets of waveforms. These waveforms may be uploaded and displayed on your PC if you have the PC Control/Analysis software.

Whenever you wish to take a "snapshot" of the voltages or currents, press [>] at the lower right corner of the keypad. All 3 voltages and all four 4 currents will be recorded for 50 milliseconds. This time-coincident snapshot of 7 waveforms is called a "waveform set". The display confirms the recording by displaying "Waveform Set #1 Stored". If [>] is pressed again, another

waveform set is stored and "Waveform Set #2 Stored" is displayed. These sets are not lost when the unit is turned off. They are only lost when they are next written over. In this example, pressing [>] will replace old waveform set #1 with a new waveform set #1.

Waveform sets allow you to save before and after snapshots to be printed later. If a setup is giving odd measurements, taking a snapshot and looking at it later can aid in understanding what the error was.

Calibrating PolyPower

PolyPower is calibrated at the factory and automatically zeros itself every second during normal use. However drift may occur over time, and provisions have been made for you to quickly recalibrate it yourself.

You may calibrate the current, voltage, and frequency readings by simply attaching to a known source, pressing [Calibra] and following the instructions. For instance, to calibrate the input voltage, simply connect the V_n and V_a test leads to a convenient power source and simultaneously measure the source with a good voltmeter (one with better than 1% accuracy). Press [Calibra] and it asks if you wish to calibrate current. Press [No/Reject] and it asks if you wish to calibrate voltage. Press [Yes/Accept] and it asks if you wish to set the input ratio. Press [No/Reject] and it asks if you wish to calibrate the V_{an} input voltage. Press [Yes/Accept] and it requests that you enter the correct voltage. Press the keys with the numbers to enter the number you read from the voltmeter. When you are done and satisfied, press [Yes/Accept] and the calibration is complete.

Setting Utility Rates

PolyPower allows you to set the utility rate used in calculating the cost of energy consumed. Presently, one simple rate is used. That rate can be displayed by pressing [Rates]. The rate can then be modified by pressing the [Incre] key to increment a digit and the [Decre] key to decrement a digit. The digit that is to be affected is underlined. Pressing [<] or [>] moves the underline left or right.
When you are satisfied with the new rate, press [Yes/Accept] to have it replace the old rate.

Administrative Functions

A collection of functions that are neither measurements nor calibrations are collected under the heading of administrative functions. They include:

      Changing the measurement mode
      Identifying the unit
      Identifying the options that are loaded
      Changing the time and date
      Changing the logging period
      Changing the "on" current level
      Changing the initial display
      Enabling/Disabling AutoTHD.

All administrative functions are available by pressing [Administrative] and following the directions.

Changing the measurement mode and enabling/disabling autoTHD have already been discussed in their own sections in this manual.

Identifying the unit results in the following being displayed:

- Serial number of the unit (its unique identity)
- Firmware revision level (what level of software is active within PolyPower)
- Hardware revision level (what level of hardware compatibility it is).

These identifiers are important in any communications with Valhalla Scientific about your unit.

Identifying the options that are loaded, results in a display such as:

      "Options: HLS4567".

This display indicates that the Harmonics Analysis Option ("H"), the Data Logging Option ("L"), and the Serial Communications ("S") are active. This information may be important in communications with Valhalla Scientific.

Changing the time and date is useful for identifying the demand period, for identifying when monitoring began, and is used to label each record of the data log (if the Data Logging Option is active). To set the time and date, press [Yes/Accept] when asked if you wish to change it. Then use [<] or [>] to position the cursor under a digit that you wish to change. Repeatedly press [Incre] or [Decre] until the digit is what you wish it to be. Do this for each digit you wish to change and then press the [Yes/Accept] key to save the new time or date.

When you request to change the logging period, you may use [<] or [>] and [Incre] and [Decre] to set the period. The period may be set from 1 second to 99 minutes. That period is used in determining the demand period and in assembling and storing data log records. Press [Yes/Accept] to save the new logging period.

Changing the "on" current is accomplished by using [<] or [>] and [Incre] and [Decre] to modify the number as was done for changing the time and date above. Press [Yes/Accept] to save the new "on" current value. Note that this value is only used in relation to the A phase current.

Changing the initial display, or "greeting", is accomplished by using [<] or [>] and [Incre] and [Decre] to modify individual characters. This approach, although tedious, is effective in

customizing the instrument for your use. If the PC Control/Analysis Option is available, the greeting may be typed directly into the PC and then downloaded to PolyPower. When repeatedly pressing [Incre], the sequence that a character goes through is :
A>B>C>...>X>Y>Z> >a>b>c>...>x>y>z> 0>1>2>...>7>8>9>->/>:>;>,>.>!>?>@>&.
Pressing [Decre] modifies the character in the opposite direction.

Specifications*

Size

    4@W x 8@L x 1:@H

Weight

    Less than 2 pounds

Operating Range

    0 - 50 degrees C (32 - 122 degrees F)

Power Requirement

    12 VDC @ 50 ma, wall mount power supply included
    Internal Ni-Cad operates up to 10 hours after overnight
    charge

Voltage

    Input Range: 1 - 600 Vrms steadystate in 6 autoranges
    Display Range: 1 - 6 megavolts (using input ratios)
    Accuracy: 0.5%
    Frequency Response: No derating of accuracy for
               harmonics through 25th harmonic (1500 Hz
               for 60 Hertz fundamental)

Current

    Input Range: 0.01 - 3000 Amps with the proper current
               probe attached
               With HA-3000: 5 - 3000 Amps
               With HA-1000: 1 - 1000 Amps
               With HA-150: 1 - 150 Amps
               With HA-100: 0.1 - 100 Amps
               With HA-10: .01 - 10 Amps
               6 autoranges

    Display Range: 1 - 6 megamps (using input ratios)
    Accuracy: 0.5% plus accuracy of current probe

Frequency Response: dependent on current probe attached
With HA-1000: no derating of accuracy for harmonics through the 25th harmonic (1500 Hz for 60 Hertz fundamental)

Frequency

Range: 45 - 66 Hz fundamental frequency
45 - 1650 Hz for RMS measurements
45 - 3000 Hz for harmonic measurements
Accuracy: 0.5%

Power, Energy, Cost, Power Factor

Display Range: 1 watt - 60 megawatts (using input ratios)
Accuracy: 1%

Harmonic Distortion:

Range: Basic unit has THD only
With Harmonic Analysis Option, individual
  harmonics through 15th (900 Hz)
With Harmonic Analysis and PC Control
  & Analysis Software, harmonics through
  50th (3000 Hz)
Accuracy: To within 1% of fundamental

Transient Detection

Minimum duration to guarantee capture: 32 usec
Measurable Range of Magnitude: $\pm$ 2500 Vpk

Captured Waveforms

Quantity: 14 waveforms organized into 2
time-coincident sets of 7 each (3 voltages
and 4 currents)

specifications are subject to change without notice.