Power Quality: Is my power good or bad?

How to use the PowerSight PS4500 Power Quality Analyzer to check your power quality.

At Summit Technology we are often asked for advice on how to check power quality.
Often the situation begins with a scenario like this:

"We keep blowing power supplies in our servers/PC's/(other equipment)."
"We are experiencing equipment malfunctions and misoperation, so we want to know if power quality is the cause."
"The service/repair technician says we have 'bad power' "!

These types of situations will require a power quality study with a power quality monitor for a month or longer to catch any disturbances. We may ultimately find that there is nothing wrong with the power at all but the only way to find out is by actually performing a power quality study. When we talk about power quality and power disturbances we use terms such as spikes and transients, voltage sags, dips, and swells. A complete loss of power, or power outage, will obviously cause equipment to malfunction. And we must include harmonics in the conversation. If you are new to power quality we'll explain these terms below. This article then describes how you can use the PowerSight PS4500 Power Quality Analyzer to perform your own power quality study.

Power Quality Terms
Sags/Dips - this a low voltage condition. Voltage sags are often momentary and last from a few cycles to minutes, or in the unusual case of a "brownout" can last for hours. A sag can also be referred to as a "dip".

Swells - this is the opposite of a low voltage condition, it's when voltage is suddenly increased. Voltage swells are often momentary and usually last just a few cycles to minutes.

Effects of voltage Sags and Swells.
All electric and electronic machines and appliances must have an adequate voltage source. If the voltage falls below a certain limit, usually specified by the manufacturer, or rises above a certain limit, the machine or appliance will mis-operate, or shut down and turn off, or become damaged.

Transients (Impulses) - are very short duration bursts of energy that show up as brief, fast-rising voltage excursions on the sine wave. You also may see the terms: "spike", "impulses" or "surge" used to describe these phenomena. They typically last for a few microseconds to several milliseconds and are commonly caused by loads turning on or off. Most electrical devices will exhibit an inrush of energy when power is first applied, to charge capacitors etc. and conversely will discharge some stored energy when turned off, generating transients. Transients can also be caused by faults on the power system, and lightning is an extreme cause of transients.

Effects of Transients.
Voltage transients can cause component damage and/or circuit signal disruption.

Damage: At high voltage levels, voltage transients cause degradation of electronic materials and devices that will lead to component breakdown. High voltages can punchthrough insulation or semiconductors, creating pin-holes in these materials or briefly "cooking" the circuitry. If repetitive, the continual stressing weakens sensitive electronics over time. As circuit components become progressively weaker the concern is that a future transient with a low peak voltage that would otherwise be safe would cause complete failure of a weakened component. At very high voltage levels instant and catastrophic failure occurs; components can literally melt. Transient voltage levels above 5 times line voltage would be considered to be severe, causing immediate damage, breakdown and failure.

Disruption: High-density electronic chips with millions of transistors work internally with very low voltage signals, as low as 2-3 volts. The high-frequency energy contained in impulses can capacitively couple unwanted voltages into electronic circuits. This “noise” inteferes with the electronics internal signal levels and can reverse 1 or 0 logic states in computing circuits. Even if no immediate damage occurs this causes computing errors.

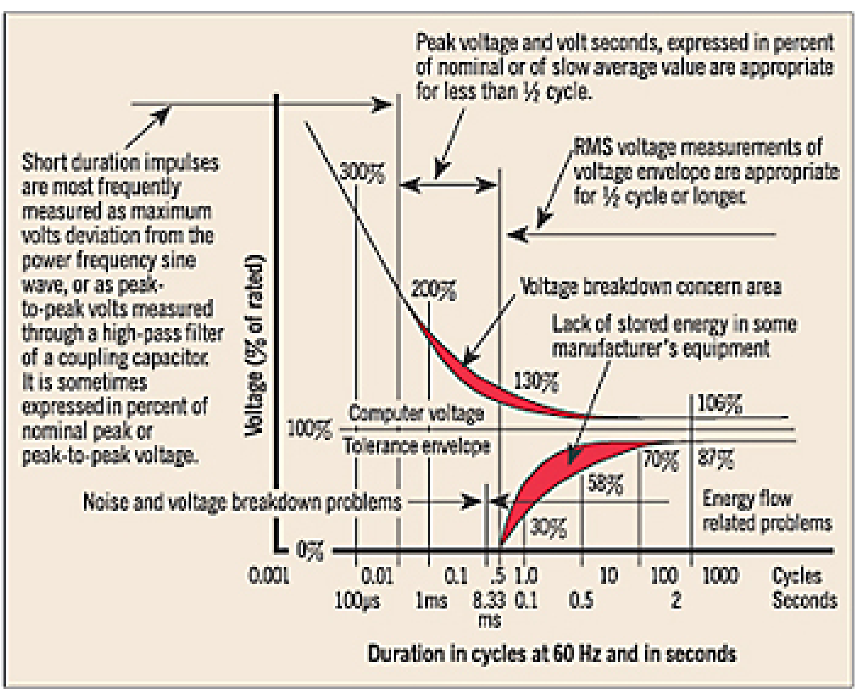
Harmonics

The measurement of harmonic distortion characterizes the “purity” of the sine wave. An ideal AC power waveform is a pure sine wave of one frequency, 50Hz or 60Hz. If other frequencies (the harmonics) are present the AC waveform becomes misshapen (distorted) and looks less like a perfect sine wave. Harmonics have to be severe to create disruption of electronic equipment. However, the main concern with harmonics is the effect they have on the infrastructure and distribution system components. High harmonics will cause transformers and conductors to overheat, reducing their useful life and contribute to premature breakdown. As a general rule of thumb, Total Harmonic Distortion for voltage should be kept below 5%.

Get Equipment Tolerance Specifications

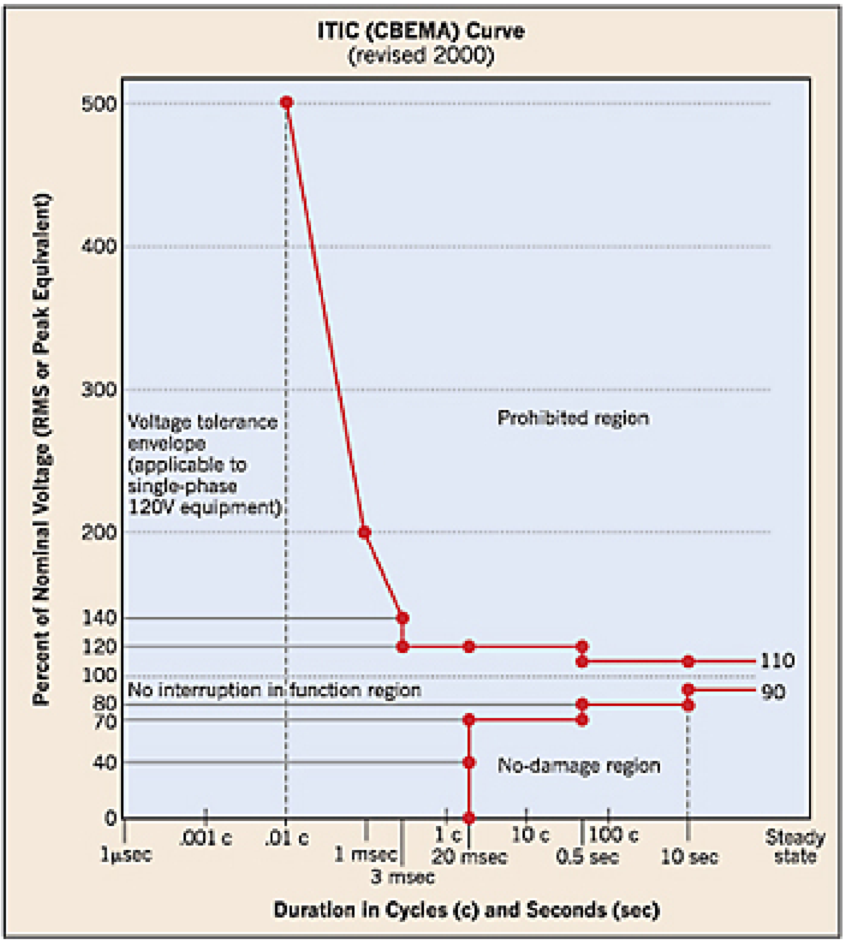
If you have an issue with electronic or electric equipment malfunction it helps to get the voltage tolerance specifications from the manufacturer. Unfortunately, some manufacturers may not specify the high and low voltage limits the equipment needs to operate reliably, or the service tech simply doesn’t know. But you should ask, especially if it is the manufacturer who is accusing ‘bad power’! Fortunately, there are well established guidelines that we can fall back on to audit power quality in the absence of published specifications; power tolerance curves.

Power Tolerance Curves



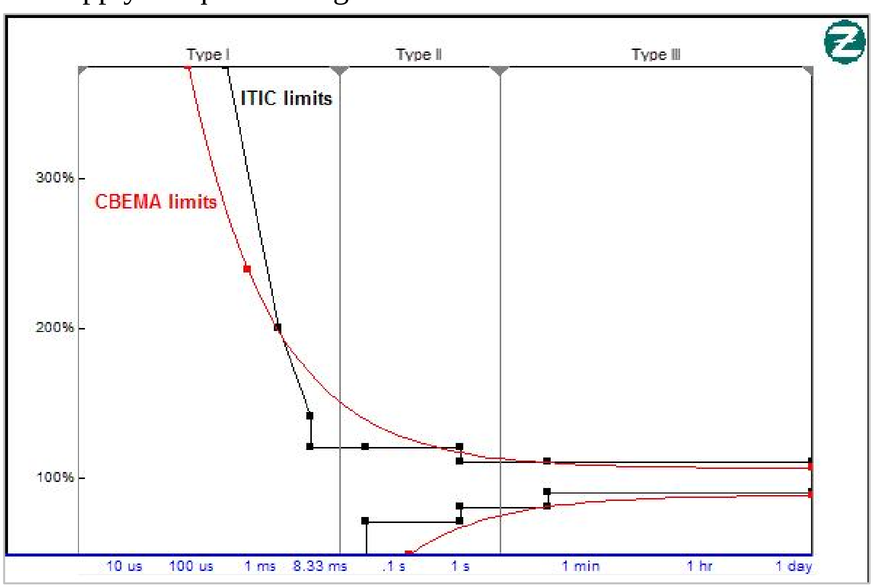
A few years ago power experts postulated curves that describe the safe operating limits for power being supplied to electronic equipment. In the absence of any standards, or other tolerance data from manufacturers, these curves have served power quality investigations quite well. The original tolerance curve is known as the CBEMA curve (Computer Business Equipment Association). Later a revised version was introduced; the ITIC curve (Information Technology Industry Council) shown below.

Both curves describe the reliable operating limits of power for



electronic equipment in the voltage domain. The curves plot the magnitude of voltage events in the y-axis against their duration in the x-axis. When we refer to sags or swells we are discussing RMS voltages, i.e. voltage measured over one cycle or greater (> 16.6 ms). Positive-going excursions from nominal voltage are commonly called surges (the preferred technical term is swells) while negative-going deviations from nominal are called sags, or dips. Voltage excursions that are sub-cycle, or less than 16.6 ms are referred to as impulses, transients or spikes.

The curves help us understand what the tolerable voltage levels should be for electronic machines. Voltages should be kept in the area within the two curved (or red) lines. Voltage excursions outside this region will cause damage or disruption. Swells are damaging while sags are disruptive. In the sub-cycle region from 8.33 ms down to 1 microsecond durations the curve suggests that equipment can withstand high voltages but only for very brief durations. Looking at the region greater than 8.33 ms voltage should not rise above 106% of nominal voltage and should not drop below 87% of nominal voltage. Swells or high voltage excursions above 106% will cause damage and/or overheating. Low voltages, dips and sags, cause insufficient energy to be provided to power supplies such that they do not supply adequate voltage levels for electrical circuits to function. Low voltages also cause relays and contactors to drop out that can shut off or cause equipment to mis-operate.



This next graph shows the two curves compared to each other. The original CBEMA curve (red) was an educated guess, while the (black) ITIC curve reflects the real-world observed experience of how voltage disturbances affect reliable operation. Both curves provide an understanding of tolerable voltage levels and events for most electronic equipment.

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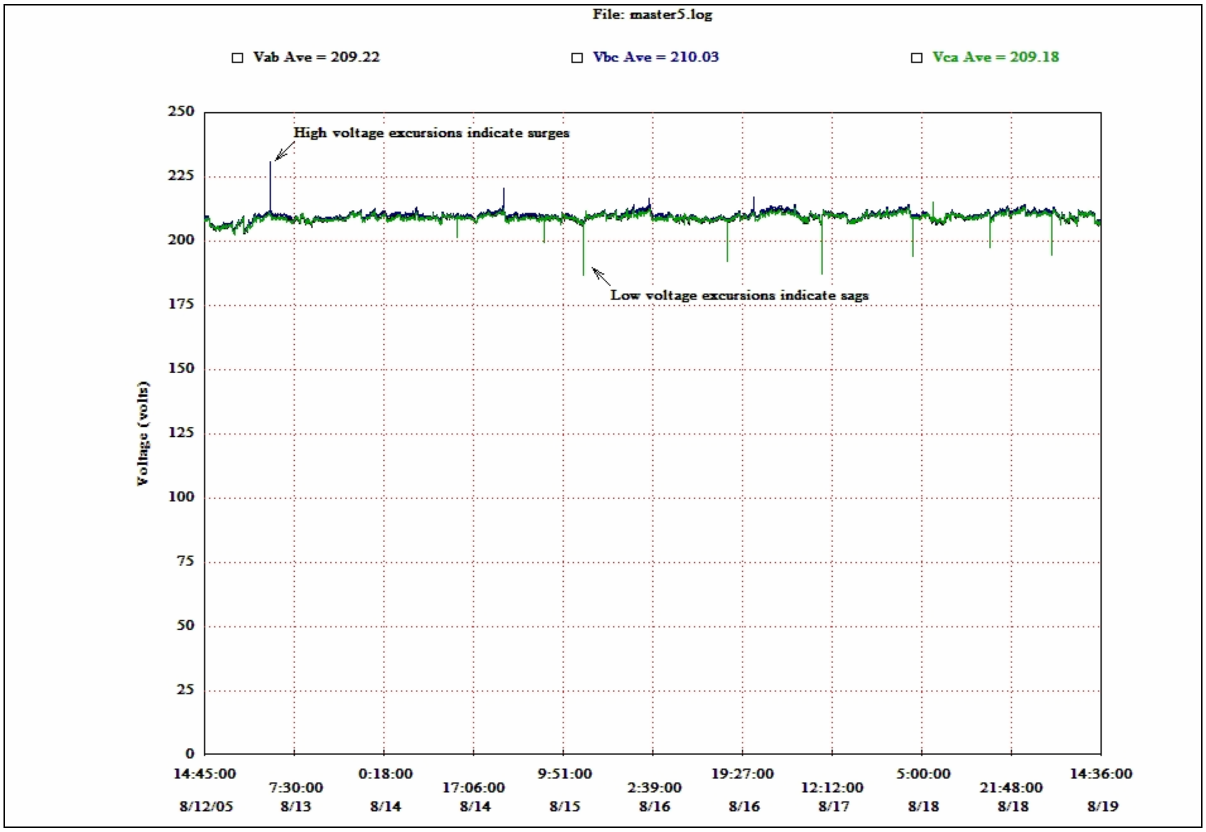
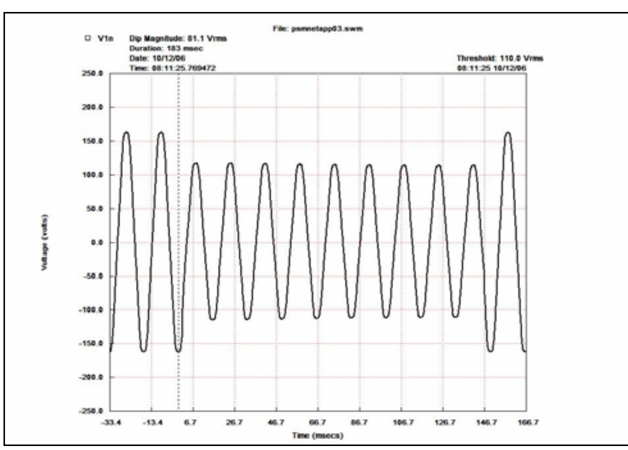
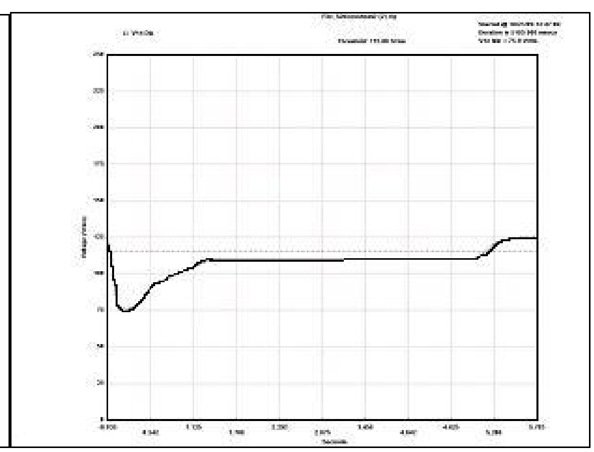
PowerSight PS4500 Reports: RMS Voltage Logs, Sags and Swells

The following graph from a PowerSight is of RMS voltage measured over time. The PowerSight PS4500 Power Quality Analyzer is designed to continuously track voltage over time, half-cycle by half-cycle. Thus, every cycle is measured; there are no blind spots or dead-times that power is not being examined and analyzed. Measuring every cycle is necessary to authentically evaluate voltage quality. (Simple data loggers do not measure every cycle, and will therefore miss sags or swells.)



With this graph it easy to notice high or low voltage excursions, it is a good starting point to examine voltage quality. Sometimes this graph is all that is needed to prove or disprove whether power quality is OK. If further detail is needed, trigger levels, or thresholds, can be programmed to catch and report sags and swells events as follows:





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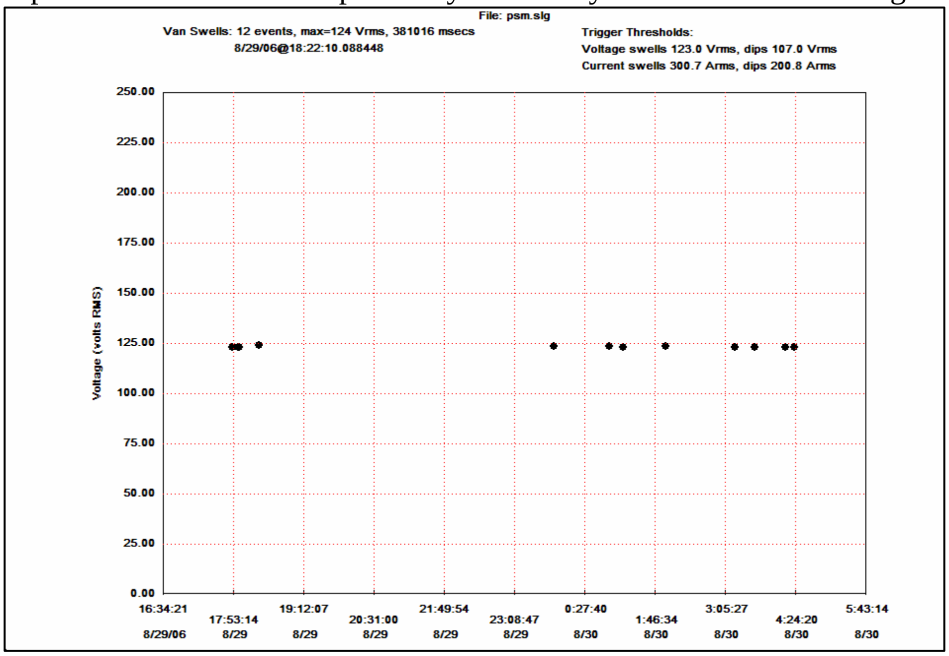
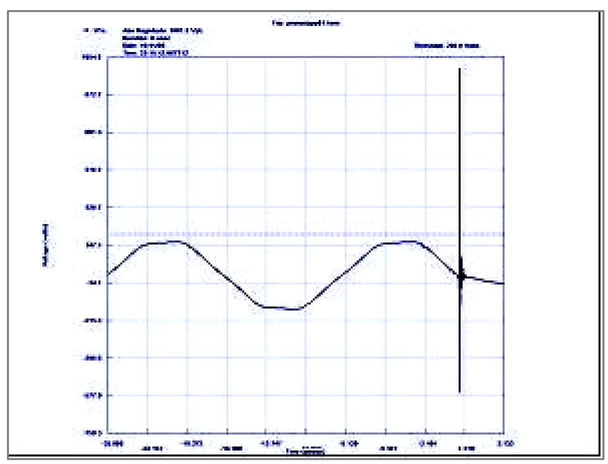
The graph on the left shows a short voltage dip lasting 8 cycles and has reported that it was 183 milliseconds long and the voltage sagged to 81 VRMS. Most electronic power supplies would probably not have enough energy stored in capacitors to ride through this event. The event was captured by programming a low voltage trigger of 110 VRMS. RMS events that are less than 10 cycles in duration are presented as sinusoids as shown. For RMS events longer than 10 cycles, the event is presented in the RMS domain, The graph on the right shows a voltage sag caused by a large load (such as a motor) turning on, then off, the event lasts for approximately 5 seconds.

The following RMS log report shows in a scatter-plot RMS events plotted over time. The Y-axis shows voltage of events and the X-axis shows time to indicate when sags or swells occurred. This report can be useful to help identify how many events occurred during monitoring, and whether events are random or occurring regularly, or if events coincide with equipment malfunctions. This report gives the number of events (12) as well as the voltage values of swell and dip events. At first glance the voltage events look harmless, however one dip event at 107 VRMS would be questionable. 10% below 120 V is 108 VRMS so it’s conceivable that one event could cause a problem.

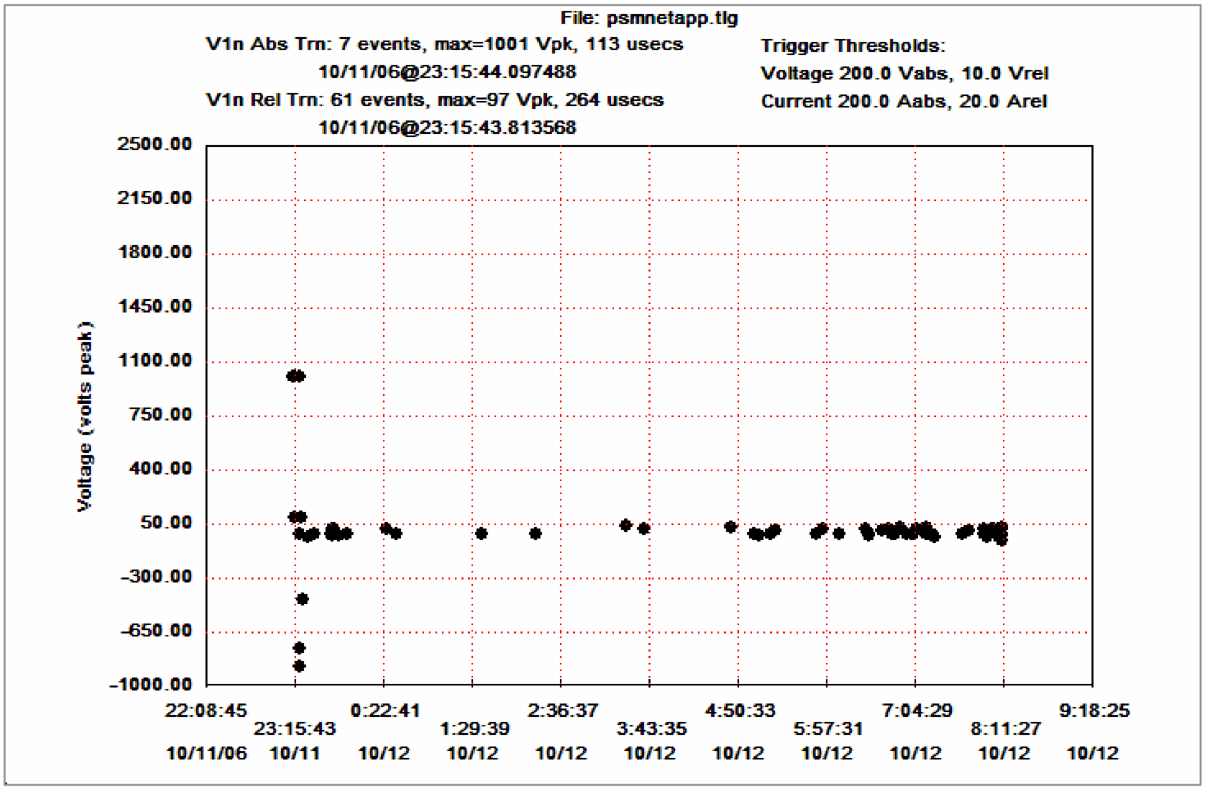


PowerSight PS4500 Reports: Transients/Impulses

The transient capture system in the PS4500 can capture sub-cycle events as brief as 8us and 1000V peak. Here’s an example. If the manufacturer of the affected equipment does not have a specification for acceptable levels of transients then using the CBEMA curve above (and based on field experience) we would suggest a maximum tolerable peak voltage level would be 2 times nominal line voltage, for events less than 1ms in duration. Transient values below 2x nominal voltage would be considered benign.

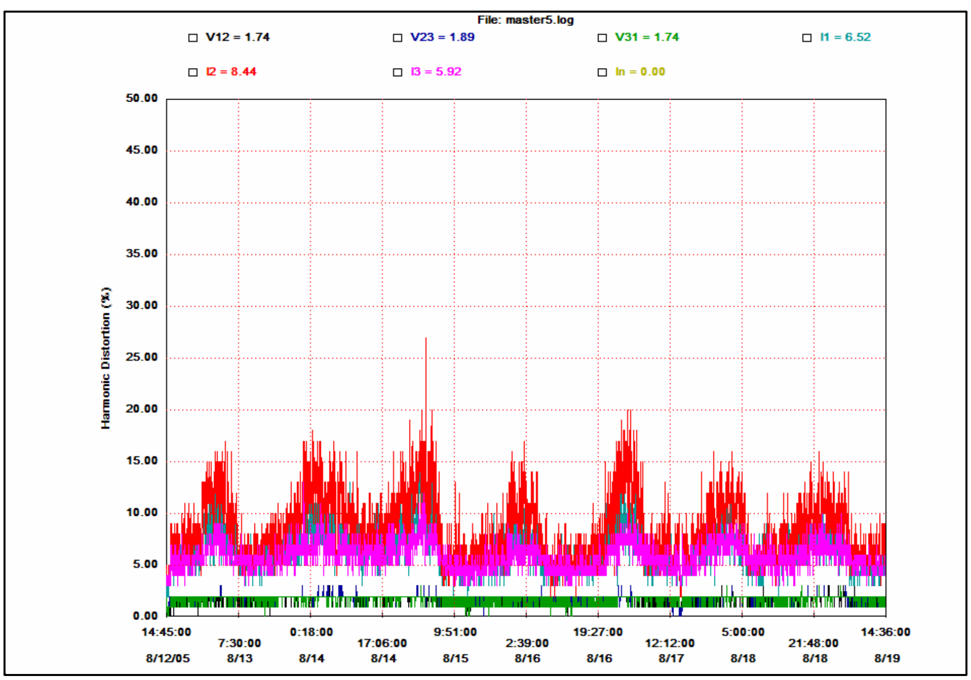


Similar to the voltage log graph is the following transient event log graph, another scatter-type presentation. The graph displays the peak voltage of a transient against time of occurrence. It helps to understand whether or not potentially damaging or disrupting transient voltage events have occurred, and how often. Again, the time position data may be helpful to notice whether transients are occurring at frequent intervals, and whether they coincide with equipment problems. In this example there is a cluster of events around 50 Vpk so they would be considered benign, but a couple of events have peak values up to 1001 volts peak and should be prevented or suppressed.



PowerSight PS4500 Reports: Harmonics Log

This graph shows THD (Total Harmonic Distortion) logged over time. It reports the maximum THD for voltage is 1.89%, well within the recommended limit of 5%. The PowerSight PS4500 Power Quality Analyzer measures harmonics, and calculates THD, to the 63rd harmonic.



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Step by Step Suggestions for a Power Quality Study

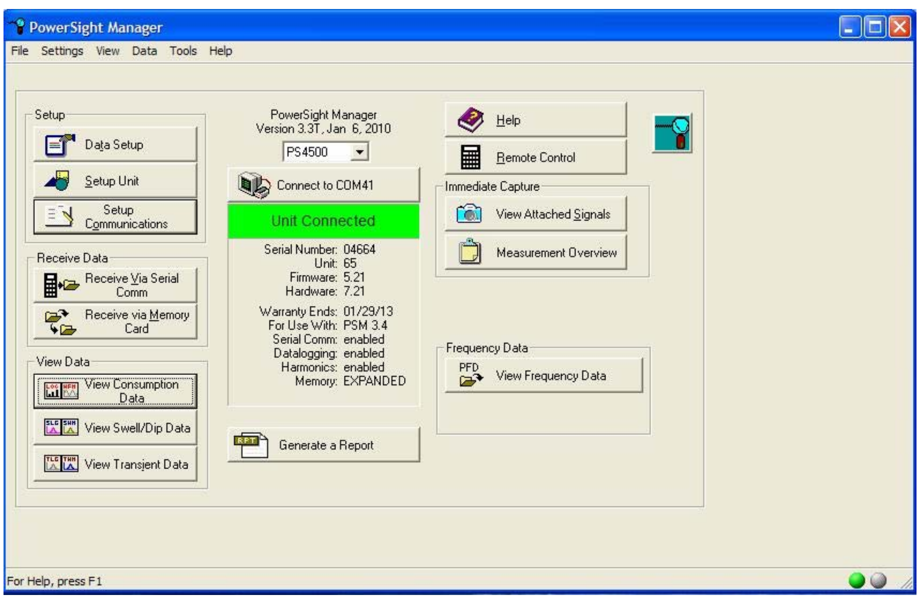
1) Prepare and plan the study:

If possible get the recommended voltage tolerance levels for the affected equipment from equipment manufacturer. If manufacturer does not provide the data, use the following guidelines:
For high voltage events (swells) set the **Voltage Swells** trigger limit at a value between 6 – 10% above nominal line voltage. E.g. for 120 V systems select a value between 127.2 and 132VRMS. 130VRMS is recommended.
For low voltage events (sags) set the **Voltage Dips** trigger at a value between 8 – 12% below nominal line voltage. E.g. for 120 V systems select a value between 110.4 and 105.6VRMS. 108 VRMS is a good setting, or 10% below nominal.
For **Absolute Transient** trigger settings pick a peak voltage value around 200% of line voltage i.e. 200 Vpk to 250 Vpk for a 120VRMS system. For the **Relative Transient** trigger level (i.e. with all 60Hz information removed) pick a value around one times line voltage. E.g. 100 Vpk for a nominal 120VRMS system. (Note that PowerSight Manager Software suggests values if you are not sure.)

2) Install the PowerSight PS4500 meter and voltage probes

Following safety procedures per NFPA 70E connect the voltage probes to the conductors and plug the leads into the voltage channels on the PowerSight. (For information on testing with safety per NFPA 70E read this paper: NFPA 70E and Electrical Testing Safety)

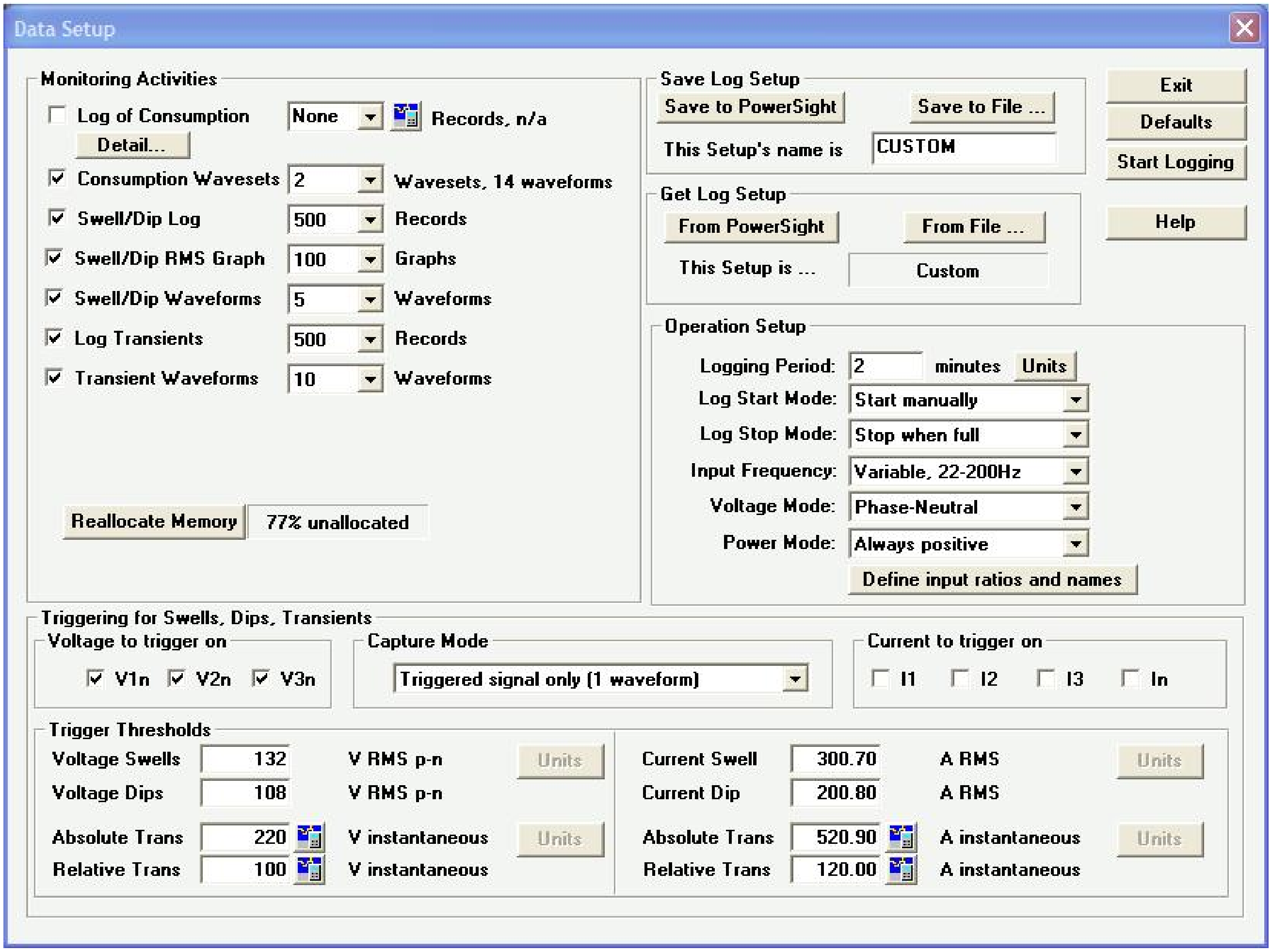
3) Link to the PS4500 PowerSight via Bluetooth and perform Set-up.



The PS4500 can be programmed from the front panel keys but most users prefer to use a PC for set-up. The PS4500 communicates via Bluetooth wireless which allows users to operate the meter remotely safely away from high voltages. Using PowerSight Manager Software, set up the trigger levels and logging interval as shown below in the **Set-Up Example** below.

Set-up Example

A typical example follows: In PowerSight Manager (PSM) link the PC to the PowerSight PS4500 via the **Connect to COMxx** button **(**xx will be the Com port your Bluetooth utility has assigned, see more instructions here: Bluetooth Instructions) then select **Data Setup**. The PS4500 measures cycle by cycle and the user decides how to reduce the data. For a week's (or less) monitoring session a logging interval period of 5 minutes (or less) would be suitable. For a month-long session a 15 minute interval would be recommended. This means that at the end of each 5 or 15 minute interval the PS4500 will save the maximum one-cycle values it recorded, the minimum one-cycle values, and the average of all the cycle-by-cycle measurements over each 5 or 15 minute period.



First uncheck the **Log of Consumption** box under **Monitoring Activities**, we will set it later. Set the **Triggering for Swells, Dips, Transient**s with the suggested values as shown. This example is for a 120/208 three phase wye configuration so we have selected triggering to occur for phase to neutral events on all voltage channels (V1n, V2n, and V3n). We have elected to record up to 500 swell/dip events in the text log and up to 100 events as RMS graphical plots. Swell/dip events that are less than 10 cycles and presented in the sinusoidal domain have been set to 5 events. The transient capture mechanism is set to 500 events as text logs and 10 detailed waveform events. Since we are conducting a voltage quality study, turn off the current triggers (deselect **Current to trigger on**).

Under **Operation Setup** we have set the logging period interval to 2 minutes. The logging of power parameters such as volts, watts, current, power factor etc. is independent of the event trigger capture system. After each 2 minutes of monitoring, the 7200 cycle by cycle measurements during that minute (60 cycles x 60 seconds x 2 minutes) will be summarized to three values; a minimum, a maximum, and average. Note under **Log Start Mode** and **Log Stop Mode** we have selected the **Start manually** and **Stop when full** settings. If you want to log any frequency fluctuations set **Input Frequency** to **Variable, 22- 200Hz**. If not, set it to Fixed; generally frequency is very stable on mains power but if you are running off a UPS or generator it's a good idea to log frequency. In this section we have told the meter the **Voltage Mode** measurements are to be calculated for **Phase-Neutral**. For a delta-configuration you would change this setting to Phase-Phase. Under **Save Log Setup** notice you can save this configuration to a file that you can recall again in a future study.

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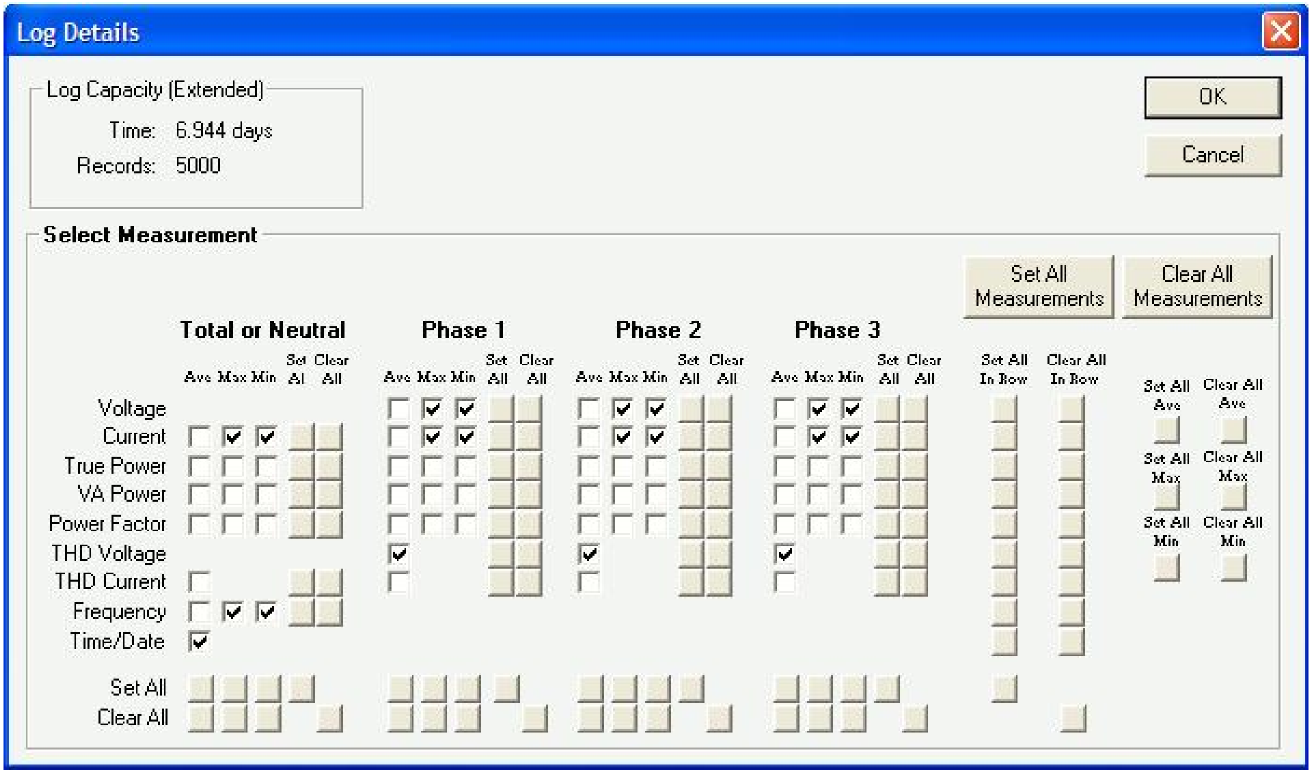
Now go back to **Log of Consumption** (leave the box unchecked still) and click **Detail.** The **Log Details** screen gives you finer control over what can be logged and what can be omitted. For this study we have decided that we only want to log Min and Max voltage excursions so that we can observe the extent of voltage excursions above or below the 120V nominal voltage; average voltage is of no concern.



Optionally for a power quality study we could connect current probes to monitor current activity. It may be helpful to see if peaks of current occur that coincide with voltage sag events, so just select Max and Min current logging. Minimum is helpful to see if a load ever went to zero amps, indicating it had turned off. **THD**, and **Frequency** Min and Max have also been selected. Check **Time/Date** to time-stamp the logs. When satisfied with the settings click OK to return to the Data Setp screen.

Go to **Log of Consumption** and now check the box. The **Data Setup** screen below will declare that with this setup configuration you can monitor for 6.944 days! For shorter or longer monitoring sessions experiment with different values.

4) Initiate Monitoring and Disconnect the PC

Before monitoring begins we recommend inserting an SD memory card up to 2GB capacity into the PS4500 memory card slot. That way data will be logged to the internal RAM memory and be backed-up onto the card as well. The card will provide another method of data transfer when the study is terminated. The PS4500 can be told to start and stop monitoring at designated times as above, or in an alternative mode can monitor until the memory is full. The user can interrupt or stop the session at any time. (But don't remove the SD card "hot" - pause the monitor first!) Once the PS4500 is monitoring, the user can disconnect the PC and leave the PS4500 to monitor.

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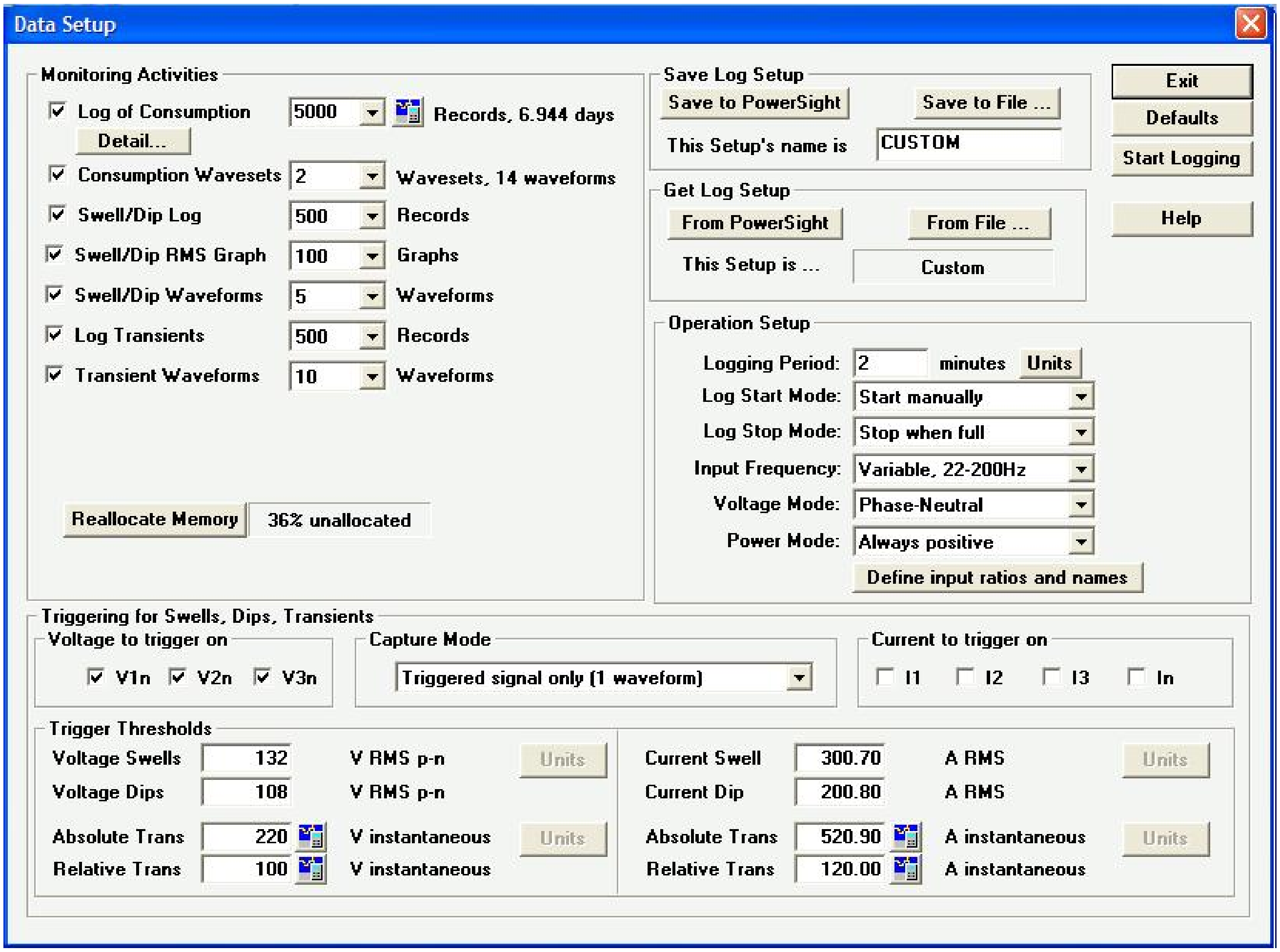

5) After Monitoring Download Data from PS4500 and Analyze

When the session has stopped the data can be downloaded to the PC for analysis using PowerSight Manager Software. The data can be downloaded either via Bluetooth wireless communications, or by transferring the SD memory card to a card reader.

Review the section above on the PowerSight PS4500 Reports and investigate whether any events occurred that are outside the manufacturer's specifications or were triggered by your user selected values.

Report Writing

The PowerSight Manager includes a Report Writer function that will automatically compile a report with summary table and graphs of all logged parameters. The RMS log graph will easily identify any voltage sag or swell events. Go here to see an example of a complete report:

http://www.powersight.com/uploads/files/PowerSight%20Auto%20Report.pdf

The Report is editable to include text comments and pictures or graphics. The author can also choose how much data to report or not report. Often the RMS log graph is all that is needed – and that is all you will get if no events were recorded! To add pictures of individual power quality events the user can cut and paste selected sag/swell events and transient event graphs. The software has a copy and paste function. Only a few of these event graphs need to be included to establish the evidence of poor power quality, so pick the worst case examples. Add the text log graphs if desired to show the quantity of captured events. Now the power study is complete and professionally documented!

Free Software to Share Survey Data

PowerSight Manager (PSM) software is **free** to download and **free** of license restrictions to permit sharing of survey data (.log files) and easier collaboration between multiple users.
Go here to download PSM: http://www.powersight.com/downloads/index.cfm?list=Software

All data is exportable to Excel. The Report Writer has two modes:
1) Summary Mode for one power study.
2) Comparison Mode for comparing the results of two studies done at different times, such as for rebalancing panels, after adding new loads or circuits, energy savings verification etc.

Conclusion

The PowerSight PS4500 Power Quality analyzer will answer the question: “Is my power good or bad?” It will also report “how bad?” by recording the voltages of events, and when events occur. If no disturbances are recorded, and RMS voltage is not fluctuating outside recommended limits (typically +/- 10%) then your power quality is “good”.

The CAT-IV rating of the PS4500 and it’s Bluetooth communications create a better user safety experience since workers can operate the meter remotely at a safe distance away from high voltages. After installing the PS4500 remote communications allows them to remove cumbersome PPE safety clothing such as gloves and visors, to be more comfortable, and safer, while testing. And the free PowerSight Manager Software makes it easy to prepare a final report.

To rent or buy a PowerSight, or to talk to a power monitoring expert, call: 408 982 9280. We’d be happy to discuss your power study application. www.powersight.com

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