Understanding Scanner Records

Power Monitors, Inc.

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1 Introduction

The job of any power monitor is to record all interesting data, and leave unrecorded the vast majority of boring, unremarkable data. The tricky part for a monitor is deciding which events are important. This is a problem of data reduction. A recorder that captured every 60 Hz waveform during a week's recording would never miss an event, but would present the user with billions of useless cycles. Conversely, a recorder whose thresholds are set incorrectly may not record *anything*. Staying somewhere between these two extremes involves a balance of thresholds, settings, and record types. The monitor will see an enormous amount of data on its voltage and current inputs– the ViP sees over 10 billion samples per day! Ideally, all this data is reduced to a small report which just shows the important events and measurements. The sifting of data into specific record types accomplishes this task.

1.1 Triggered Record Types

PMI Scanner records can be divided into two classes. The first is event driven. These record types are triggered by a combination of triggering logic and adjustable thresholds, usually voltage-based. If a trigger never happens, nothing is recorded for that record type. As more triggers occur, more records are collected for that record type. The advantage of this class is that nothing is recorded unless something happens. In the ideal case, no problems occured, so nothing was recorded, and no data analysis is necessary. If a trigger did occur, then the monitor logged the event for later analysis. This is a powerful data-reduction tool, and can reduce huge amounts of data into a few small records containing all the significant events. The disadvantage is that success completely depends on good thresholds and settings. A threshold that is too tight will cause the Scanner to log records that aren't really worth analyzing. These extraneous records often hide the (hopefully) few important ones. A threshold that is too loose will cause the Scanner to ignore important disturbances. Although it is often possible to use regulatory limits or other known standards to set threholds, this can be a chicken-and-the-egg type problem: sometimes you need to know something about the disturbance before you can set proper thresholds to capture it. Despite these potential pitfalls, triggered record types are powerful tools in powerline monitoring. They are most useful for capturing voltage disturbances and power quality problems. The captured events are usually presented in a text report. Triggered record types include Power Outage, Abnormal Voltage, Event Change, Significant Change, Loose Neutral, and Waveform Capture.

1.2 Non-triggered Record Types

The second class of record types is not event driven. These record types are always logging data, regardless of how interesting or important the data is. The classic example is a paper stripchart, which continuously logs data. There are no thresholds to set, although there may be a parameter to determine how often to collect data. The logged data is usually presented as a graph of data points. Although there may be a large amount of data, using a graph lets the eye pick out important data. Problems such as sags and swells are easy to see in the Stripchart graphs. In addition to voltage quality studies, these record types are used for finding daily trends in current or power values, measuring power factor, etc. The advantage of not having thresholds to set is that there is no question about what data will be recorded. The disadvantage is that sometimes there is no question that *a lot* of data will be recorded, most of it unimportant. For non- power quality data such as power factor measurement, there is no disadvantage. These record types include Stripcharts, Daily Profiles, Histograms, and Energy Usage.

1.3 Using the Scanner

The PMI Scanner can record every available record type simultaneously. Each record type has its own fixed memory allocation, so there is no danger of one errant record type filling the Scanner memory to the exclusion of other record types (for example, Event Capture can never overflow into Stripchart memory). Thus the choice usually isn't what to record types to record, but what record types to examine. In order to answer that question, a good understanding of each record type is required. The details of each record type, and potential uses, are described in the following sections.

2 Stripcharts

The Stripchart is one of the most useful record types. In a single Stripchart graph, you can see power quality events such as single-cycle voltage sags and current surges, as well as long term voltage trends. With the graph, an entire recording session can be examined at a glance.

2.1 What's Recorded

The only setting for the Stripchart is the Stripchart Interval. This Interval, which can be as small as one second to as large as four hours, determines how often the Scanner takes a Stripchart data point. Every Stripchart the Scanner is recording uses the same Interval setting. During the Interval period, the Scanner keeps a history of the largest and smallest one-cycle values for each Stripchart, as well as a running average. At the end of the Interval, the max, min, and average values for that time period are recorded as a Stripchart data point. For example, if the Stripchart Interval is set to one minute (a typical setting), at the end of each minute, the Voltage Stripchart will record the average RMS voltage, the minimum one-cycle RMS voltage, and the maximum one-cycle RMS voltage, all during that minute. All of the 3600 60Hz cycles during that minute are used to calculate the average, and for max/min detection.

These values are presented to the user as three traces on a graph: a maximum, a minimum, and an average. The average trace roughly corresponds to a graph from a paper stripchart recorder. The maximum and minimum graphs are unique, however. Each gives the worst case value for every Interval, with single-cycle measurement resolution.

Each Scanner has at least enough memory to record Stripcharts for a week with a one minute Interval. When the Stripchart data fills the Stripchart memory, the Scanner has two options: it can either stop recording Stripcharts, or go into "wrap-around" mode. In "wrap-around" mode, the oldest Stripchart data points are erased to make room for the new ones as they are collected, which allows the Scanner to always have the latest data. This choice is made by the user during the Initialization. If the "Enable Stripchart Wraparound" box is checked, the Scanner will go into "wrap-around" mode as needed, otherwise it will stop Stripchart recording when memory is full. This does not affect other record types. For example, if there is memory for one week of Stripcharts, and the Scanner was left in the field for three weeks, it would either have the first or the last week's Stripchart data, depending on the wrap-around setting.

Every Scanner can record a Stripchart of voltage. Some Scanners can also record a Stripchart of current. The Vipcan also record Stripcharts for real, reactive, and apparent power, power factor, phase angle, THD, and harmonics. The Vip , with harmonics, can record over 200 Stripcharts at once. Typically, only a few are needed at one time. All the Stripcharts share the same memory, so enabling more Stripcharts reduces the total Stripchart recording time.

When creating a Stripchart graph or report, any "gaps" in the data due to a power outage are filled with zeroes. This happens when the Scanner loses power, and its rechargeable battery (if present) runs down.

2.2 Typical Settings and Suggested Uses

There are three settings for the Stripchart record types. The primary setting is the Stripchart Interval. This time setting determines how often the Stripchart data is recorded. Since the Stripcharts always give worst case one-cycle max and min values, the Interval can be set to any time value without a loss of measurement resolution. For example, even if the Interval is set to 15 minutes, the maximum and minimum one-cycle RMS values for each 15 minute period are recorded. What *is* lost by setting the Interval to larger values is time information. If there is a voltage minimum of 90 volts RMS during a Stripchart interval, with the Interval set to 15 minutes, you are sure that voltage dipped that low for at least a cycle, but you don't know *when* or *how often* or *how long* during that 15 minutes it happened. A smaller Interval, such as one minute, provides a finer time resolution. The smallest Interval, one second, gives excellent time resolution, but consumes memory 60 times faster than a one minute setting. Often, the exact time of a voltage dip is not as important as the size– for this case, any reasonable Interval setting is fine.

The most common setting is one minute. This is a good balance between frequent data collection and long recording time. Since most loads that start and stop usually run for longer than a minute, the start and stop effects (such as inrush current) are easily spotted in the Stripchart. An example is an air conditioner load: a forty minute period of cycling on and off is obvious in the Stripchart graph as twenty data points at one load current, then twenty data points at low current, all connected by straight lines on the graph. The first interval of the high current period will probably have a much larger current maximum than the rest due to the starting current of the air conditioner. The voltage interval will probably have a dip at the same time.

The most frequent reason to use an Interval smaller than one minute is for large loads that cycle on and off more frequently than one minute. For example, if an elevator is causing power quality problems, and it only takes 10 or 20 seconds to start at one floor and stop at another, a one second Interval is probably necessary, otherwise the entire elevator travel will occur during a single Stripchart Interval. In this case, the Scanner should not be left to record for days, since it would only hold the last few hours of Stripchart data. The best use in this case is to set the Stripchart to one second, then cycle the load (such as the elevator) for a while, in an attempt to reproduce the problem, then download the Scanner. In general, the Interval should be smaller than the quickest cycling time of a problem load.

The most frequent reason to use an Interval larger than one minute is to increase the recording time. Setting the Interval to two minutes doubles the recording time, without a serious loss of time resolution. Other common settings are five and fifteen minutes, used to match metering or billing increments or regulatory time periods.

The second Stripchart setting is the "Stripchart Wrap-Around" mode. The best setting for this depends on how the Scanner will be used. Some users leave a Scanner at a problem site until the customer calls with a power quality complaint. The Scanner is set to a small Interval such as one minute or thirty seconds, and Wrap-Around is enabled. Because Wrap-Around is enabled, the Stripcharts always have the latest few days of data in memory, by discarding the old data. The Scanner is downloaded, and has the most recent days of Stripchart data in memory, no matter how long it was recording. This recent data will have the voltage disturbance in it. Other users will disable Wrap-Around, and leave a Scanner at a problem site where the power quality problem will definitely occur soon. The Scanner will record the first week or so of Stripchart data, then stop Stripchart recording. The Scanner can be downloaded at any time later, knowing that the beginning of the recording session is locked in memory, and will not be overwritten. Other users always download the Scanner before it fills up Stripchart memory, which make the Wrap-Around setting irrelevant. The choice depends on how the Scanner will be used. The factory default setting is for Wrap-Around to be enabled.

The third Stripchart setting is which Stripcharts are enabled. For voltage-only Scanners, there is no choice: a voltage Stripchart is always recorded. For Scanners that can record current, the current Stripchart can be turned off to extend the recording time of the voltage Stripchart. It is usually better to increase the Interval time instead of disabling current to get more recording time. For the VipScanner, there are many more Stripcharts to enable or disable. The choice depends on what information is needed. If a power factor study is being performed, for example, turn on power factor, and possibly apparent power and displacement power factor. If a power quality problem is present, only voltage and current may be necessary, although adding Total Harmonic Distortion (THD) may be useful to see if harmonics are present. The total recording time is shown by Winscan as Stripcharts are enabled and disabled during the Scanner setup. Another method to increase Stripchart memory is to reduce the number of recorded channels. If only three channels are needed on the Vip, changing the number of channels from four to three gives 25% more recording time.

For quantities such as power factor, phase angle, THD, etc. often the average is much more important than the one-cycle max and mins. The max and min traces on the graph may be turned off so that they don't obscure the average trace.

2.3 Examples

[Need pictures of 1 second and 1 minute demo files]

3 Daily Profiles

The Daily Profiles are used to spot daily trends in voltage, current, power factor, etc. The entire recording session is combined to form the "average" 24-hour day, which is plotted on a graph like a stripchart. Power quality issues are usually not addressed with Daily Profiles (except perhaps consistently low or high line voltage or harmonic distortion). Rather, average line conditions such as regulation voltage, load current, etc. are profiled.

3.1 What's Recorded

Each measured quantity has only one Daily Profile per channel in a recording session. For example, there are four voltage Daily Profiles in a recording session, one per channel. The Profile is averaged over the entire recording session. This average is created by dividing the 24-hour day into 96 time periods, each 15 minutes long. During each 15 minute period, the Scanner computes the average value for that Profile (voltage, current, etc.). This 15 minute average is then averaged with all the previous days' averages of that 15 minute period. For example, the first Voltage Daily Profile data point is the average voltage during the 15 minute period from 12:00am to 12:15am, averaged again over the entire recording time. If a Scanner is recording for a week, then this 12:00-12:15am period is averaged seven times over the entire week.

There are no settings for Daily Profiles. All available Daily Profiles in a Scanner are always enabled, regardless of the settings for any other record types. Memory does not run out for a Daily Profile; it just keeps averaging as long as the recording session lasts (there is a practical limit of about a year). Some Scanners record just a voltage Profile, others voltage and current. The ViP Scanner records a Profile for voltage, current, real, reactive and apparent power, power factor, displacement power factor, voltage and current THD, and phase angle.

3.2 Suggested Uses

Daily Profiles are typically used to profile or characterize a parameter, such as average load current or power factor. Since the Profile is supposed to reflect average line conditions, the more loads included in the recording, the better the average. Monitoring a single small load such as a small office building would not create a very good profile of distribution line conditions (such as distribution line power factor), since the building would be a small part of the total distribution load. Voltage is somewhat of an exception in that anywhere can be good place to create a profile: every other load (at least those nearby) will see the same distribution line voltage. The ideal location for creating power factor profiles is where a PFC would be placed to correct power factor.

The voltage Daily Profile is normally used to identify voltage regulation problems, or other steady-state low/high voltage issues. The current Profile can be used to identify daily trends in load current. This is also possible with the apparent power Profile. Power factor and reactive power Profiles can be used to set PFC timers to correct for power factor only when necessary during the day. The voltage and current THD Profiles show when harmonic distortion is present during the day.

The more days the Scanner records, the better the average created by the Profile. A recording session that just lasts a single day doesn't incorporate any daily averaging at all. Since a Profile starts with all zeros, a recording session that doesn't even last 24 hours will include some 15 minute blocks with the data still zeroed. A recording session that doesn't even last 15 minutes will have all zeroes for a Daily Profile.

A Stripchart can also be used for profiling tasks, but is not ideal. The stripchart interval is usually set to an interval faster than 15 minutes; a fast interval can show too much information, making it hard to form a good average Profile. Often the stripchart only has enough memory for a week or two, limiting the averaging time; the Daily Profiles have no such limit. Most importantly, the stripchart does not divide the data into an averaged day period, so it can difficult to spot daily trends in the graph.

3.3 Examples

[typical voltage daily profile - high voltage at night, low during the day] [typical current thd profile - bad during the day, good at night]

4 Cycle Histograms

The cycle histograms contain valuable power quality information as well as information for distribution line profiling. Questions such as "what were the absolute highest and lowest RMS voltage?", "how many cycles was the voltage below 80 volts?", and "what are the most common load currents?" are easily answered. The histograms also contain the raw data necessary to answer more complicated statistical questions such as "what is the probability of a voltage sag below 100 volts?" and "what high and low limits does the line voltage meet 99.99% of the time?". Where the Daily Profiles give average current, power factor, etc. for distribution profiling, the histograms show what values are the most common– the "mode" in statistical terms.

4.1 What's Recorded

A Histogram divides a measurement range into many bins. For example, in the Vip, the voltage Histogram divides the 600V voltage range into 600 bins, each one volt wide, giving a bin for zero volts, a bin for one volt, two volts, all the way to 600 volts. After each 60Hz cycle is measured, the voltage is rounded to the nearest volt and "put" in the appropriate bin. The bins are really counters that count how many cycles were at that voltage. If the 108 volt bin has a count of 45, then there have been 45 cycles with an RMS voltage of exactly 108 volts, sometime during the recording session. The Histogram throws away time information: those 45 cycles could have occurred anytime during the recording session. They may have been 45 cycles in a row, or three 15-cycle sags, or 45 isolated sags spread out during the entire recording session. (To recover the time information, use the Stripchart or an event-based report.)

Every Stripchart max and min value will have a non-zero count in the corresponding Histogram. For example, if the voltage Stripchart shows six sags to 108 volts sometime during the recording session, there should be a count of at least six in the Histogram at 108 volts. The count will probably be somewhat larger, unless each sag was only one cycle long.

There are no settings for Histograms. All available Histograms in a Scanner are always enabled, regardless of the settings for any other record types. Memory does not run out for a Histogram; it just keeps classifying measurements into the bins (by incrementing the bin counters) as long as the recording session lasts.

The 600V (iVS-3/600), the S-series (VS-1S and iVS-1S), and the Vip record a voltage cycle Histogram for each voltage channel. The Vip also records cycle Histograms of current, real, reactive, and apparent power, power factor, displacement power factor, and phase angle.

4.2 Suggested Uses

The power of the Histogram is that *every cycle* is included in the report. Every cycle during the recording session is reflected in the count of one of the bins. If all the counts in a Histogram are totaled, the result is how many cycles the recording session lasted (minus any time under a power outage).

Histograms are presented as a bar graph and a report. The report is in some ways easier to read than the graph. The absolute highest and lowest voltages during the recording session are found by finding the highest and lowest bins with a non-zero count. At that point you also know how many cycles the voltage was at those extremes, and by glancing at the nearby bins, you know how many cycles the voltage was near those extremes. For example, if all the bins below 110 volts are zero, then you immediately know that there was not even a single cycle of voltage below 110 volts anytime during the recording session. If the count at 111 volts is 1,352,200, then the voltage was at 111 volts for over 6 hours $(1,352,200/(60 \times 60 \times 60))$. By totaling the counts for all the bins in a voltage range (for example, 0 to 90 volts), you find how many cycles the voltage was in that range.

More complicated power quality questions can be answered by exporting the histogram data to a spreadsheet. By dividing each count by the total of all the counts, the histogram data is normalized, and can represent a sample probability distribution function. If a normal, or bell-shaped probability distribution is fit to this data, a standard deviation is created that can be used to answer "what high and low limits does the line voltage meet 99.99% of the time?". A cumulative sum over the data will convert the distribution function into a sample cumulative probability function. Correlations between channels can be performed by comparing the probability functions of channels.

For the voltage histogram, most of the time the user is interested in the few cycles that are outside certain limits, not the vast majority of cycles that are perfectly normal. These few cycles usually represent power quality issues. The current, power, and power factor histograms are useful for distribution line or load profiling. For these histograms, the few cycles at the extremes are usually unimportant: the vast majority in the middle is the good data.

4.3 Examples

[example of voltage histogram, with 2 or 3 volt imbalance, and sag] [real power histogram]

5 Minute Histograms

The Minute Histogram provides a much "smoother" version of the Cycle Histogram. Quick sags and swells are averaged out of the data, to show the nominal voltage or current level every minute. Voltage regulation problems are easy to see in the Minute Histogram.

5.1 What's Recorded

The Minute Histogram is similar to the Cycle Histogram. During each minute of the recording session, the voltage is averaged (every cycle is included). At the end of the minute, the Histogram bin counter for that average value is incremented. The result is a

Histogram of one minute average voltages, instead of one cycle voltages. For example, if the voltage were 123 volts for 55 seconds, then 115 volts for 5 seconds, the average would be 122 volts, and the 122 volt bin counter would be incremented. If the Stripchart interval is also set to one minute, then the Stripchart voltage averages will match the Minute Histogram counts.

Like the Cycle Histograms, there are no settings for the Minute Histogram. All available Minute Histograms in a Scanner are always recorded, regardless of the settings for any other record types. Memory does not run out for a Minute Histogram; it just keeps classifying measurements into the bins (by incrementing the bin counters) as long as the recording session lasts.

All Scanners record a voltage Minute Histogram. Scanners that can measure current also record a current Minute Histogram.

5.2 Suggested Uses

The voltage Minute Histogram can reveal voltage regulation problems. Ideally, the line voltage should be at the same value every minute. The larger the spread in the Minute Histogram, the more the voltage is varying. The center of the spread is (hopefully) the target regulation voltage. This information is also present to an extent in the voltage Stripchart, depending on the recording interval and amount of memory. Because the Stripchart spreads out the voltage averages as a time graph, it can be more difficult to gauge how long the voltage was at certain levels (although it may be easier to see *why* the voltage was moving).

The Minute Histogram is also better for this analysis because it does not run out of memory, and is always set for one minute averaging.

The current Minute Histogram shows average load current on a minute basis. The maximum and average load currents are easily spotted on the Histogram as the edge and the center of the current spread. Again, this information is usually in the current Stripchart, but not as easy to see.

The cycle Histograms can also be used for voltage regulation problems and load profiling, but the Minute Histograms can be easier to read since the fast one-cycle events have been averaged out.

5.3 Examples

[voltage minute histogram of same data as voltage cycle histogram] [current minute histogram of same data as real power cycle histogram]

6 Energy Usage

The Energy Usage report shows the accumulated real, reactive, and apparent power measured by the Scanner. The accumulated real power is energy, in kilowatt-hours. The accumulated reactive and apparent powers are kilovar-hours and kilovolt-amp-hours, respectively. These totals are for the entire recordings session, and are only available on Scanners which can compute power.

6.1 What's Recorded

Each cycle, the real, reactive, and apparent power values are computed and added to the running totals for the recording session. These values include the effects of voltage and current harmonics. The accumulated powers are totaled separately for each channel for a wye hookup. With a delta hookup, the individual phase powers cannot be measured, only the total. In this case, the three phase total real, reactive, and apparent power values are totaled and reported.

Negative power values are included in the accumulation. For example, if a load is both absorbing and generating power (at different times, of course), the accumulated power will reflect it. A line that varies from leading to lagging power factor may have a small accumulated reactive power reading, even though at different times the actual reactive power flow was large. This would happen if the negative vars accumulated during the periods of leading power factor mostly cancelled the positive vars during the periods of lagging power factor.

6.2 Typical Settings and Suggested Uses

There are no settings for the Energy Usage report. This report can be used to measure energy consumption of a monitored load, or accumulated reactive power in power factor studies. A revenue meter that doesn't total negative power, or doesn't include the effects of harmonics, may show readings that differ from this report.

6.3 Examples

[an example of the Energy Usage report]

7 Significant Change

The Significant Change record type tracks quick fluctuations in the line voltage, with single-cycle response, while ignoring gradual changes. Voltage events are timestamped to the second, and listed in a report. If the report is empty, there were no voltage events that exceeded the trigger threshold. This is a quick way to gauge the voltage power quality, because only voltage fluctuations exceeding the threshold are listed.

7.1 Trigger Logic

The Significant Change record type uses a voltage threshold parameter. At the end of each second during the recording session, the largest and smallest RMS voltages for that second are compared with the "standard" Significant Change voltage. This standard voltage starts as the nominal voltage picked by the Scanner during the two minute countdown (typically 120, 208, 240, 277, or 480 volts). If the difference between the standard voltage and either the maximum or minimum voltage was more than the threshold, a Significant Change is recorded. In addition, the voltage (either the max or min) that caused the trigger becomes the new "standard" until the *next* Significant Change.

As an example, consider a "standard" voltage of 119 volts, and a threshold of 2 volts. After 40 seconds, the voltage drops to 118 volts. No Significant Change is recorded because the 1 volt change is smaller than the 2 volt threshold. After another 35 seconds the voltage increase to 120 volts. The change is 2 volts, from 118 to 120, but no Significant Change occurs because 120 volts is only 1 volt greater than the "standard" of 119. After another 23 seconds the voltage increases to 121 volts. A Significant Change is triggered because the 1 volt increase created a 2 volt difference between the 121 maximum voltage for that second, and the 119 volt standard. The standard voltage is now set to 121 volts, until the next Significant Change.

Only one Significant Change per second can be recorded per channel. If both the single-cycle max and min meet the threshold in the same second, the voltage that is furthest from the standard become the new standard.

7.2 What's Recorded

When a Significant Change is triggered, the triggering voltage is recorded, along with a date and timestamp (to the second), and the channel number.

Significant Change is recorded separately for each voltage channel (although they share the same voltage threshold parameter). If Significant Change memory is filled, Significant Change recording stops. All voltage channels use the same Significant Change memory. The amount of memory used for Significant Change is different for various Scanners, but every Scanner can record hundreds, and most over one thousand records.

On most Scanners, Significant Change is always enabled for recording. On some older Scanners, enabling Flicker recording disables Significant Change recording. This is true for the VP-1, and 300 volts Scanners (the VS-3, VS-1, VS-1M, iVS-3, iVS-1, and iVS-1M) with serial numbers below 6000.

7.3 Typical Settings and Suggested Uses

The default setting for the Significant Change threshold is 3 volts. This setting can be as small as 1 volt or as large as 8 volts. Normally, a threshold between 2 and 5 volts is appropriate, depending on the nominal voltage. A single-cycle disturbance such as a sag will trigger Significant Change if the sag is greater than the threshold. If this happens, the sag voltage becomes the standard, which will trigger another Significant Change if the voltage returns its previous level.

The Significant Change report is very useful for determining how often, and to what degree the line voltage is fluctuating. If there are no Significant Change records, then there were no fluctuations greater than the threshold. A Significant Change record can be correlated with the Stripchart by using its timestamp. Find the same time period in the Stripchart to see what the voltage and current were before and after. This may give some indication of the cause of the disturbance. All Significant Change records during a Stripchart interval will be included in a single Stripchart max/min/average data point. For example, if the interval is one minute, and six Significant Changes occur within one minute, they may all fall into the same Stripchart data point. (Of course they are still reported individually in the Significant Change report). The Significant Change report provides more detail than the Stripchart for these disturbances.

A key advantage of the Significant Change report is that only one disturbance per channel can be triggered each second. If multiple disturbances occur during a second, the worst one is recorded. This limits the size of the report, making it much easier to analyze, while still giving single-cycle response. If detailed disturbance information on a cycle basis is required, use the Event Change report. Event Change gives much more detail, but is more complicated to examine. The timestamp of a Significant Change event can be used to find the same disturbance in the Event Change report for further analysis.

For even more detail, Waveform Capture can be used (if available). If the disturbance triggered Waveform Capture, the raw waveforms of each voltage and current channel can be displayed. Again, the Significant timestamp is used to find the waveform in the list of captured waveforms.

7.4 Examples

[excerpt from significant change report, from same data as voltage stripchart]

8 Event Change

The Event Change report provides detailed cycle-level information about each voltage disturbance. This is the most detailed report available short of actually looking at raw waveforms with Waveform Capture. An event is triggered when the voltage moves past any of a series of trip points. Max and min voltages and currents during the event, the event duration (in cycles), and the current before and after the event are all recorded.

8.1 Trigger Logic

Event Change triggering involves three parameters. The first, the Nominal voltage, sets a baseline voltage level. This is not the same nominal voltage selected by the Abnormal Voltage record type during the two minute countdown. The Event Change Nominal voltage is specified by the user, and is not picked by the Scanner. The second parameter is the Threshold, in volts. The Threshold is added and subtracted to the Nominal to form voltage trip points. These trip points are created all the way down to zero volts and up to the maximum Scanner voltage by using multiples of the Threshold. For example, a Nominal of 120 and a Threshold of 6 would create trip points at $120 \pm 6 = 114, 126; 120 \pm 2 \times 6 = 108, 132; 120 \pm 3 \times 6 = 102, 138$; etc.

The voltage region around the Nominal, but before any trip points (115 to 125 volts in the above example) is the Nominal Band. If the voltage moves from the Nominal Band to cross a trip point, an Event Change is triggered. This Event Change continues until the voltage either returns back into the Nominal Band, or moves past another trip point. Each time the voltage moves past another trip point, the existing Event Change ends and a new Event Change is triggered. The trip points can be visualized as a grid (every 6 volts in the above example) from zero volts to the maximum Scanner voltage, and any time the line voltage crosses a grid line, an Event Change is triggered.

There is one exception to the previous paragraph. The third setting, Holdoff Time, specifies in cycles how long to wait before allowing a new Event Change, if the voltage continues moving in the same direction. This setting is to prevent a slow sag from generating multiple Event Changes. For example, consider a Nominal of 120, a Threshold of 6, and a Holdoff Time of 10 cycles. The line voltage is 119 volts, and no Event Change has been triggered. Now a slow sag occurs. The voltage drops to 114 volts, triggering an Event Change. The next cycle, the voltage keeps dropping to 110 volts. On the third cycle, the voltage drops to 105 volts. This would normally cause the Event Change to end and a new one to be triggered, since the voltage crossed another trip point. However, with the Holdoff Time set to 10 cycles, no new Event Changes can be triggered for 10 cycles, as long as the voltage continues to drop. If the voltage changed direction and started to rise, then the Holdoff Time would not apply– if the voltage rose past a trip point, the existing Event Change would end and a new one would start. The Holdoff Time doesn't prevent Event Change from capturing short events, but keeps a slow voltage change from generating multiple events.

Event Change can be triggered by any voltage channel. The triggering logic (and settings) are separate for each channel. Another channel may trigger its own Event Change while other channels have running Events, resulting in overlapping Events.

8.2 What's Recorded

When an Event Change is triggered, the trigger time is recorded, with one cycle resolution. The RMS current one cycle *before* the trigger is recorded. The direction of the voltage change, or slope, is also recorded. This is displayed in Winscan as a minus for a sag and a plus for a swell. While the event is ocurring, the Scanner keeps track of the max and min current and voltage values. When the event ends, the max and min RMS voltage and currents are recorded, along with the duration (in cycles). One cycle later, the RMS currents are measured to record the currents *after* the event.

All voltage and current measurements are recorded for every channel, regardless of which channel triggered the event. If a sag occurs on three phases simultaneously, three Events will be triggered at the same time. These Events are recorded separately, even though they may have the same data in them.

8.3 Typical Settings and Suggested Uses

The Nominal voltage should be set as close as possible to the actual nominal line voltage. If a circuit normally runs at about 117 volts, use 117 as the Nominal, not 120. Event Change is not for steady-state line voltage regulation problems (like the Abnormal Voltage report), but for quick sags and swells. The Threshold should be set small enough to catch problem events, but large enough to avoid filling up memory with unimportant data. A good start is 5% of the Nominal. The Nominal and Threshold can be set separately for each channel. These should be set accordingly if some channels see different voltage levels (for example, in a single phase setting where two channels are connected line to ground, and the third channel line to line.) To effectively disable Event Change on a channel, set its Threshold to something huge, like 500 volts.

The Holdoff Time is not as critical. Ideally, this is set to just larger than the slowest anticipated sag time. For example, if no sags (such as from motor starts, etc.) will take longer than 6 cycles for the voltage to drop to the sag value, the best Holdoff Time is 7 cycles. This will prevent multiple Events Changes from the same voltage sag. Otherwise, as the voltage dropped lower and lower, past voltage trip points, Events would continue to be triggered. Ideally, only one Event is triggered for a single sag or swell. A typical value is 10 cycles. This is longer than most sags take to reach the final sag voltage.

Event Change provides cycle-level detail on sags and swells. A sag which merely shows up as a single point on the Stripchart can be analyzed in the Event Change report. Usually, Event Change is not the first report to analyze in a Scanner recording, due to its complexity. Check the voltage Stripchart for min or max voltages out of tolerance, or the Significant Change report for voltage fluctuations. If a disturbance needs further study, use the timestamp to find the fluctuation in the Event Change report. Here detailed information such as cycle duration, pre- and post-event RMS currents, etc. are available.

The most useful values are the duration and max and min voltages. This information shows how long the event lasted, and how low or high the voltage went. The cycle timestamp can be useful to determine how far apart several events were which ocurred in the same second. The timestamp is also used to correlate an Event Change with other reports, such as Significant Change and Waveform Capture.

The pre- and post- RMS current can be used to determine whether the load being monitored caused a sag. Consider a sag that triggers an Event Change. If the current one cycle before the event is low, but the max current during the event is high, and the current one cycle after is high (or at least higher than the pre-trigger current), the monitored load probably caused the event. In-rush current from a motor start will cause this type of pattern: the high in-rush current pulls the voltage down, triggering an event. When the in-rush current peak is over, the voltage goes back up, ending the event. The final current is lower than the in-rush current, but higher than the current before the event.

Another possibility is a voltage sag where the current during the event is lower than the pre-trigger current (or about the same), and the post-trigger current is about the same. Here, the monitored load probably did not cause the event. Some other load pulled the voltage down, and the monitored load current dropped proportionately with the lowered voltage. When the voltage came back up, the current rose to its normal level also.

Winscan groups closely occuring Event Change records into super-events. A super-event is started when an Event starts on any channel. The super-event lasts until there are no running Events on all channels for at least an entire second. A complicated voltage disturbance may trigger several closely spaced or back-to-back Event Changes, but will be grouped into a single super-event for easier analysis.

Event Change is recorded separately for each voltage channel. If Event Change memory is filled, Event Change recording stops. All voltage channels use the same Event Change memory. The amount of memory used for Event Change is different for various Scanners, but every Scanner with Event Change can record hundreds, and most over one thousand records.

8.4 Examples

[example from same data as significant change] [example showing monitored load causing sag]

9 Power Outage

The Power Outage report lists the date and time of all outages during the recording session. An outage is defined by the Scanner to be a voltage sag below 80 volts, lasting for at least 1/3 of a second. Only channel one's voltage is used to trigger an outage. The beginning and end of the outage are timestamped. In the report, the duration is also given, along with the total number of outages and the total outage time.

If the Scanner has battery ride-through capability, it will continue to record Histograms, Stripcharts, etc. during the outage. If there is no battery, or if the battery runs down, the Scanner loses power and stops recording. When power is restored, the Scanner records the end of that power outage and resumes recording normally.

A power outage often triggers Waveform Capture, which may help reveal the cause of the outage.

9.1 Examples

[a typical power outage report]

10 Flicker

The Flicker record type is designed to show voltage variations that cause lights to flicker. The Scanner defaults to the threshold of irritation curve from IEEE Standard 141. This curve is designed to show only voltage flicker that is perceived as irritating. When this occurs, a flicker event is recorded with the time and magnitude.

10.1 Trigger Logic

A Flicker curve is specified by a list of allowable voltage thresholds, and a and a limit on their quantity in certain time spans. The default curve allows 5 voltage fluctuations of 1% or greater, in a ten second period; 10 fluctuations of 1.5% or greater, in a one minute period, and so on up to 10 fluctuations of 6 % or greater, in a 24 hour period. In general, the larger the voltage variation, the less often it is allowed before triggering a Flicker record. There are nine pre-set time periods used, from 10 seconds to 24 hours. Each has an adjustable threshold percentage and event limit. If the voltage variations exceed the threshold percentage more than the number of times allowed by the limit, in a certain time period, then a Flicker record is triggered.

For example, with the default settings, if the voltage varies more than 1% over 5 times in a ten second period, a Flicker record is generated. These variations also count for the longer Flicker time spans if they are large enough.

Flicker is computed once per second, based on the previous second's one-cycle max, min, and one second average RMS voltage levels. The thresholds are given as a percentage. If the max, min or average differ from each other by more than the percentage for a certain time period, then a flicker event counter is incremented. If the counter value exceeds the limit for a certain time period, a Flicker record is triggered.

Flicker is triggered separately for each voltage channel.

10.2 What's Recorded

When a Flicker record is created, the date and time are recorded, along with the number of voltage events that exceeded the tolerance. The time span over which the flicker occurred is also recorded. Each channel is reported separately.

10.3 Typical Settings and Suggested Uses

The Flicker report is designed to show whether utility customers will perceive voltage variations as flickering lights. The default curve is programmed to generate Flicker events when a person would become irritated by the level of Flicker. The IEEE also has a curve which shows when a person would just perceive flickering, lights, but not become irritated. The validity of these curves depends on individual circumstances such as lighting (the curves assume 120V incandescent) and customer sensitivity.

The Flicker report is used both to confirm a customer complaint about flickering lights, and to measure progress in mitigating a problem. If no Flicker events were recorded, then no voltage variations occured which exceeded the allowed limits, and the problem may have been solved. Since flickering light perception is so subjective, merely showing a customer a Flicker report which shows no flicker according to a standard curve may lessen the complaint by showing that the voltage variations are within standard limits.

Flicker is recorded separately for each voltage channel. If Flicker memory is filled, Flicker recording stops. All voltage channels use the same Flicker memory. The amount of memory used for Flicker is different for various Scanners, but every Scanner with Flicker can record hundreds, and most over one thousand records.

It is important to connect any unused voltage clip leads together, or in parallel with another voltage channel, to avoid generating bogus Flicker records. The threshold parameter is a percent change value, and applying a small percentage to an already small voltage creates tiny thresholds that are constantly exceeded. Flicker is not meaningful on neutral to ground voltage channels: only channels that are used to power lighting generate meaningful Flicker data.

On most Scanners, Flicker is always enabled for recording. On some older Scanners, enabling Significant Change recording disables Flicker recording. This is true for the VP-1, and 300 volts Scanners (the VS-3, VS-1, VS-1M, iVS-3, iVS-1, and iVS-1M) with serial numbers below 6000.

10.4 Examples

[a typical flicker report, showing some flicker]

11 Abnormal Voltage

The Abnormal Voltage record type shows if the average line voltage moved past a low or high threshold from the nominal voltage. On some Scanners, the low threshold exceedence is indicated by a green LED on the front panel, and the high threshold exceedence by a red LED. When the trigger occurs, the event is timestamped to the nearest second. There is a separate LED and report for each voltage channel.

11.1 Trigger Logic

The triggering logic uses a low and high threshold, a nominal voltage, and a trigger duration. The thresholds are added and subtracted to the nominal voltage to find triggering points. If the voltage crosses a triggering point for longer than the trigger duration, an Abnormal Voltage event occurs.

The Scanner is initialized with a list of potential nominal voltages (such as 120, 240, etc.), with low and high voltage thresholds for each. The actual nominal is picked by the Scanner during the two minute countdown. The average voltage during the countdown is compared to each of the nominals; the closest one becomes the nominal voltage for the entire recording session. There are five standard nominals in the software setup (120, 208, 240, 277, and 480 volts), and two custom nominals. The custom nominals can be set to any voltage. It is possible to enable and disable the standard and custom nominals. For example, if you wanted to force the Scanner to use 230 volts as the nominal, the standard nominals should be disabled, and both custom nominals set to 230. If the standard nominals were not disabled, there would be a chance for the Scanner to pick 240 volts during the two minute countdown, if the line voltage happened to be running closer to 240 than 230 at that time. The nominal is chosen by the Scanner separately for each voltage channel.

There are separate high and low thresholds for each of the seven nominal voltages. The applicable thresholds are used once a nominal is selected by the Scanner after the two minute countdown. Voltage channels are handled separately; there is a complete set of nominals and thresholds for each. This is useful for situations such as a hot-leg delta, where one voltage channel is at a different voltage, or in a single phase setup where two channels are connected line-to-neutral, and one channel is line-to-line. The Scanner will automatically select the correct nominal and thresholds for the different line voltages on each channel.

The last Abnormal Voltage parameter is a trigger duration, in seconds. This specifies how many seconds in a row the voltage must exceed the threshold before the Abnormal Voltage record is triggered.

At the end of each second during the recording session, the Scanner compares the one-second average voltage with the nominal and the low and high thresholds. Each threshold actually creates two trip points, one above the nominal and one below. For example, consider a setup where the nominal is 120 volts, the low threshold is 6, and the high 12. The low trip points become 120 ± 6, or 114 and 126 volts. The high trip points are 120 ± 12, or 108 and 132 volts. If the one-second average voltage rises above 126 or falls below 114 volts for longer than the trigger duration, the low Abnormal Voltage trigger occurs. This event is timestamped, and the green LED is lit (if present). If the voltage goes past either high trigger point (108 or 132 volts) for longer than the trigger duration, the high Abnormal Voltage trigger fires. This is timestamped, and the red LED is lit (if present). It is possible for the low and high triggers to fire at the same time.

The use of one-second average voltages eliminates false triggering due to momentary sags and swells. Abnormal Voltage is designed to trigger for average line voltage exceptions, not sub-second events.

Once an LED indicator is lit due to an Abnormal Voltage trigger, it stays one for the rest of the recording session, even if the voltage returns to the nominal. The LED indication of an Abnormal voltage trigger can be disabled through the software. The event is still recorded normally, but no LEDs are lit.

11.2 What's Recorded

When Abnormal Voltage is triggered, the date and time, along with the channel and triggering voltage are recorded. There is a separate listing for each voltage channel, as well as low and high thresholds. Only the first trigger for each threshold is recorded.

11.3 Typical Settings and Suggested Uses

The Abnormal Voltage report is used to determine whether the voltage drifted outside the thresholds during the recording session. Since the LED indicators stay lit after a trigger, they can be used to see at a glance whether a Scanner needs to be downloaded due to line voltage problems. Usually the Abnormal Voltage report is used to get a quick read of whether there was any line voltage drift- if so, then other record types such as the Stripchart and Significant Change are used for more information.

The default threshold settings are at 5% and 10% of the nominal voltage (for example, 6 and 12 volts for the 120 volt nominal). The high threshold must be larger than the low threshold. The two custom nominals are preset at 106 and 230 volts, but should be changed if a different nominal is in use. The default trigger duration is five seconds, and can be set as small as one second, or as large as 255 seconds.

11.4 Examples

[an example of an abnormal voltage report]

12 Loose Neutral

The Loose Neutral report shows whether the typical symptoms of a loose neutral have occurred. This report is intended for single phase services, with voltage channels one and two connected from line to neutral. Only a two-channel Scanner, or a Scanner set to use two channels, can record a Loose Neutral. The symptom of a loose neutral condition is for one voltage leg to rise in voltage, and the other to fall, with the sum of the two voltages remaining close to twice the nominal voltage. For example, if the voltages start at 119 and 121 volts, then move to 105 and 135 volts, a loose neutral is a likely cause: one leg went up, one went down, and the sum is close to twice the nominal (240 volts).

This happens when the load is not balanced, and the neutral is disconnected. If this condition is met for long enough, the Loose Neutral report is triggered.

12.1 Trigger Logic

The Loose Neutral logic uses three parameters: duration, range, and difference. These parameters are used to judge whether one voltage leg has risen, and one fallen, while the sum remained the same. The difference is a voltage that specificies the minimum difference between the two legs. For example, if the difference is 16 volts, then there must be at least a 16 volt separation between the two legs. The range is a voltage that specificies how close the sum of the two voltages must be to twice the nominal. For example, a range of 12 volts means that the sum of the two legs must be within 12 volts of twice the nominal voltage. Both the range and the difference conditions must be met for at least the number of seconds specified by the duration. If the duration is set to 5 seconds, then the difference and range conditions must be met for 5 consecutive seconds before a loose neutral is declared. One-second average voltages are used. The nominal voltage is the nominal determined during the two minute countdown by the Abnormal Voltage record type, and is typically 120 volts in a single-phase hookup.

As an example, assume the difference parameter is 16 volts, and the range 12 volts, with a duration of 5 seconds. The two line voltages are 119 and 121 volts. Then one leg moves to 128 volts, and the other to 110 volts. The difference between the two legs is 18 volts, which meets the difference threshold. The sum of the two voltages is 238 volts, which is within the required 12 volts (specified by the range value) of twice the nominal (240 volts). If these voltages persist for 5 seconds in a row, then a Loose Neutral record will be triggered.

If one voltage leg changes due to heavy loading, the range parameter keeps the loose neutral from false triggering. For example, if the voltages start at 119 and 121 volts, then a heavy load to channel 1 causes it to drop to 105 volts, with the other leg still at 121, the difference condition is met ($121 - 105 > 12$), but the range condition is not met: $105 + 121 = 226$, and 226 volts is not within 12 volts of the 240 volt nominal.

12.2 What's Recorded

The date and time of the loose neutral triggering is recorded, along with the voltage on the two channels. Only the first occurrence of a Loose Neutral is recorded; if the conditions are met again, nothing further happens. The Loose Neutral report shows whether the neutral may have a bad connection, not the exact times the connection was made and broken.

12.3 Typical Settings and Suggested Uses

The Loose Neutral Report can show the *symptoms* of an actual loose neutral connection. It is worth investigating if the report is triggered. However, it is possible for the Loose Neutral logic to be fooled. If both legs are equally loaded, then the two voltages will remain the same even if the neutral is removed. This will prevent the Loose Neutral trigger from firing. It is also possible for one leg to rise and one to fall due to grossly different loading, and not from an actual loose connection. Thus it is possible for a Loose Neutral to trigger falsely, when there is no loose connection.

12.4 Examples

[an example of loose neutral]

13 Waveform Capture

Waveform Capture provides the most detailed report possible: the raw voltage and current waveforms themselves are recorded. With clues provided by the waveform shapes, it is sometimes possible to determine the cause of a voltage disturbance. Events such as capacitors opening and closing, reclosers operating, and lightning strikes can sometimes produce distinctive shapes. The voltage waveforms also reveal the exact duration and magnitude of an event, and how much was coupled across phases. Waveform Capture is also useful during steady-state conditions. The current waveshapes can show harmonic currents from non-linear loads, and the voltage waveshapes show the distortion due to harmonic currents and transformer loading. It takes a huge amount of memory to store raw waveforms. The memory size of a single 3-cycle Waveform Capture record is larger than the size of four hours of Stripchart data (at one minute intervals).

13.1 Trigger Logic

Waveform Capture uses a single threshold for triggering. This threshold is a percentage. At the end of each 60Hz cycle, the RMS voltage for that cycle is compared with the RMS voltage of the previous cycle. If the percent change in RMS value is greater than the threshold, Waveform Capture is triggered. Any voltage channel can trigger waveform capture. The voltage must be at least 5 volts to trigger. If a trigger occurs, the waveform data is recorded. The trigger test is repeated every cycle, so if the RMS voltage keeps changing, Waveform Capture will continue to be triggered, until the voltage stabilizes.

Waveform Capture can be triggered manually from the front panel of the Scanner. This produces a three cycle Capture.

If a Waveform Capture trigger doesn't occur at all during a recording session, a one cycle Capture is still recorded. This waveform is taken at the very end of the session.

13.2 What's Recorded

When a trigger occurs, the waveform data for the triggering cycle is recorded, along with the date and time (to the nearest cycle). The waveform data for the previous cycle is also recorded, to provide a pre-trigger waveform. All voltage and current waveshapes are recorded, regardless of which channel caused the trigger. The waveforms of the next cycle are also recorded, to provide a post-trigger waveform. This creates a three cycle Waveform

Capture record. If the trigger condition is met again on the next cycle, then an additional cycle of waveforms is added. In general, the Waveform Capture record continues until one cycle after the triggering stops. If the voltage is fluctuating wildy, the entire Waveform Capture memory could be filled by a very long Waveform Capture record. If the Waveform Capture memory is full before the end of the event, the Scanner erases cycles of the earliest record to make room for the new data.

The waveform data is presented as a graph and a report. The report is usually used only if the data will be exported to a spreadsheet.

13.3 Typical Settings and Suggested Uses

The default setting is 2%. With this threshold, the RMS voltage has to change by at least 2% in a single cycle. If the threshold is too tight, Waveform Capture will trigger so often that useless events overwrite the important waveforms. A Waveform Capture report consisting of just one very long record is an indication that the setting is too small. A report where all the waveform records occured during the last few minutes of the recording session is another indicator of too small a threshold. In both these cases, the trigger was being met too often. Of course, if no waveform records are present, either the threshold was too large, or the voltage quality was too good. The optimal setting varies from system to system.

The exact nature of a voltage disturbance can be seen in the Waveform Capture report. The peak voltage, length of the sag or swell, and the coupling from phase to phase are easily seen in the graph. Sometimes there are clues regarding the cause of a voltage disturbance. A voltage sag that starts in the middle of a cycle but ends at a zero-crossing can be produced by a gas arrestor. The arc continues until the voltage reaches zero, then the arc is extinguished. A recloser operation usually begins and ends at random points in the cycle. A voltage sag that is preceded by an increase in current, but followed by a decrease in current, is usually cause by the monitored load. If the current went down during the sag, and was steady before and after, the sag was probably *not* caused by the monitored load.

Each triggered event is often captured by the Significant Change and Event Change reports. The min or max voltage is usually in the Stripchart as well. These reports can be used to place the Waveform Capture record into the proper overall context. Use the timestamps for each record type to correlate the different reports.

A manual trigger captures the voltage and current waveforms during steady-state conditions (unless the user happened to press the button at the exact moment of a disturbance). Transformer saturation often shows in a flattened voltage waveshape. If the positive voltage half-cycle is a different shape than the negative half-cycle, even-order voltage harmonics are present. Often the current waveforms will not be sinusiodal. The less they look like a sinewave, the higher the level of current harmonics. Frequently, the neutral current looks much less sinusiodal than the line currents, due to the fact that some harmonics don't cancel out in a three phase system, even with a balanced load. The more the current waveform is shifted from the voltage waveform, the worse the power factor.

It is important to provide a clean ending to a recording session when using Waveform Capture. If the Scanner is still recording while the voltage leads are disconnected from the line, several Waveform Capture records will be recorded as the voltage drops to zero on each channel. These useless records of the voltage leads being disconnected can overwrite the valuable recorded data. If the Scanner will be downloaded in the field, a serial cable can be connected with the voltage leads still attached. The Scanner will detect the cable and stop recording cleanly. Otherwise, the front panel menus should be used to bring up the “STOP” option. Selecting this option stops the recording session cleanly. The voltage leads can then be removed.

13.4 Examples

[example of a half-cycle dropout] [example of bad steady-state voltage and current waveforms]