Power Quality monitoring technology, where it started, where it is now and where it can go.
Modern Power Quality monitors are based on computer technology which has advanced at an incredible rate. Within a generation computer technology has changed from desk top computers with 48K of memory to wearable computers with almost 200,000 times more memory.

At the same time the cost of memory has decreased exponentially from $350,000 per GigaByte to 5¢ per GigaByte. The processing power of computers has also increased at a similar rate.

These advancements in computer technology have directly influenced the advancements in Power Quality instrument technology.
Before the 1980’s power system engineers relied on chart recorders and analog meters to monitor power quality.

The 1980’s saw the introduction of digital power quality analyzers. Early digital instruments had limited memory and limited processing power much like the Apple II computer. As computer technology developed the capabilities of these digital instruments became more sophisticated however the basic structure of the instruments remained the same.
Voltage and current signals are isolated, filtered and digitized. Various electrical parameters such as RMS voltage and current, power, power factor, THD, harmonics, flicker, etc. are calculated and stored in memory for later viewing, analyzing and archiving. It was found that results from different instruments could be inconsistent. To ensure that different instruments measuring the same signals gave the same results the power quality measurement standard, IEC 61000-4-30, first published in 2003, was developed. While conforming to this standard is useful for compliance investigations it is not necessarily useful for power system diagnostic purposes. However designs with the latest technology will enable Power Quality monitors to be able to do both.

Advancements in computer technology have given rise to the development of “Big Data” and the need for “Data Analytics” to deal with big data.
Many different “Big Data” applications including government security programs, digital photography, video streaming and cloud data storage are pushing technology to develop faster processors, higher memory densities and more sophisticated software.

For Power Quality applications there are two types of “Big Data”. One is derived from multiple sources and the other is high resolution data recorded by individual Power Quality monitors. This presentation is about “Big Data” from individual Power Quality monitors.

With Big Data and precise, synchronized time stamps obtained from the Global Positioning System the development of a new class of Power System monitors is now realizable. These instruments will store synchronized high resolution voltage and current waveform data for use with offline Data Analytics algorithms.
Instead of storing only processed data the new class of PQ monitors will be able to do basic data processing at the same time as streaming high resolution continuous waveform data to memory. This will allow post processing of the data for both compliance and diagnostic purposes.

What will the recorded data be? Voltage and current waveforms along with basic processed values such as RMS voltage and current with ½ cycle resolution can be recorded. Data will be sampled either synchronously with the power system frequency using a Digital Phase Lock Loop or with a fixed sampling frequency. Data will be time stamped with microsecond resolution synchronized to a common clock signal accessible almost anywhere in the world. The recording will be continuous with no gaps.
What are the memory requirements? Consider a three phase system with 3 voltages and 3 currents sampled at 256 samples/cycle with 16 bit resolution. Half a terabyte of data, which will fit in one SD memory card will be enough memory for a month of continuous waveform data.

How do we deal with continuous waveform data? Software algorithms can be developed to analyse continuous waveform data with respect to compliance standards such as IEC 61000-4-30.

Analyzing continuous waveform data for diagnostic purposes is a little more difficult as this often involves detailed data analysis and is an evolving field of research.
One method of working with continuous waveform data is called a “Cyclic Histogram” which was developed by EPRI. This involves building a multicolour representation of the waveform from a continuous series of waveforms. This allows quick visual identification of when there is an anomaly and the frequency of occurrence.

Another method uses ½ cycle minimum and maximum RMS values to get a quick overview of the data. Areas of interest can quickly be found either visually or by a software algorithm designed to detect data anomalies.
Here is an example of how this would work. This is 24 hours of data sampled at 1024 times per cycle – every cycle. A data file with waveforms for 6 channels would be over 70 GB of data. RMS only data with 12 cycle average and ½ cycle min and max is only 250 MB which is much easier to deal with. From the RMS data a point of interest can be quickly identified either manually or with a software algorithm. The waveforms at the point of interest can then be graphed and analyzed.

The voltage waveforms show that this is a sag that went down to 68% of the nominal voltage for 4 ½ cycles. This is the typical signature of a fault occurring on an adjacent feeder with a breaker or automatic recloser isolating the fault within 4 ½cycles.
This sag is just outside the normal operating region of the ITI curve but well inside the SEMI F47 curve.
What can continuous waveform data be used for?

There are many applications besides compliance testing that will benefit from this data and there will be new applications not yet thought of that will benefit from the availability of archived data.

Some examples are:

**Power system forensics:**

Synchrophasor analysis is a new area of research that is being considered to increase power system reliability and stability. It is useful to observe historical Synchrophasor data to analyze power system stability before, during and after a fault. With high resolution, precisely time stamped waveform data from a number of nodes over a wide area Synchrophasors can be calculated, compared and analyzed.

**Incipient fault detection:**

Being able to go back in time, pre-fault condition, and analyze data for subtle anomalies will enable the development of algorithms to detect pre-fault indicators before the fault occurs.

**Power System Performance:**

Analysis of waveform data can give us a deeper understanding of the operation of the power system and how it responds to different stimuli.
Here is an example that was used to determine the effect of starting a 5500 HP motor with a softstarter on a medium voltage distribution line. With gapless voltage and current waveforms continuously recorded no trigger levels were required and there was no concern that the data would not be captured during the short startup transient. All aspects of the motor start can be closely analyzed.

The RMS data shows a cap bank being connected just before the softstarter is engaged. You can see the voltage increase due to the cap bank and the voltage decrease when the softstarter is engaged.
Waveforms for any part of the motor start can be examined. The capacitor bank energization transient is over in about 4 cycles. The Softstarter transient is interesting, you can see the current starts off leading the voltage by 90 degrees and within 2 cycles it has completely switched to lagging by 90 degrees. At the end of the start cycle as the motor is reaching synchronous speed current oscillations are observed.

While not suitable for all situations I believe that Continuous Waveform recording will play an important role in future Power Quality investigations.
Thank You.
Questions?

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