UNIT-4

POWER QUALITY MONITORING

Terms and Definitions

Spectrum analyzer	An instrument used for the analysis and measurement of signals throughout the electromagnetic spectrum. Spectrum analyzers are available for sub audio, audio, and radio-frequency measurements, as well as for microwave and optical signal measurements.
Swept heterodyne technique	Any signal at the input, at a frequency such that the difference between its frequency and the local oscillator is within the bandwidth of an intermediate- frequency filter, will be detected and will vertically deflect the spot on the display by an amount proportional to the amplitude of the input signal being analyzed.
FFT (or) digital technique	The signal to be analyzed is converted to a digital signal by using an analog to digital converter, and the digital signal is processed by using the FFT algorithm. The algorithm analyzes the time domain waveform, computes the frequency components present, and displays the results.
tracking generator	The tracking generator enhances the applications of spectrum analyzers. Its output delivers a swept signal whose instantaneous frequency is always equal to the input tuned frequency of the analyzer.
harmonic analyzer	Spectrum analyzers covering up to typically 100 kHz can also be called harmonic analyzers.

Concepts

Power Quality Benchmarking Process:

The typical steps in the power quality benchmarking process are

1. ***Select benchmarking metrics.*** The EPRI RBM project defined several performance indices for evaluating the electric service quality.
2. ***Collect power quality data.*** This involves the placement of power quality monitors on the system and characterization of the performance of the system.
3. ***Select the benchmark.*** This could be based on past performance, a standard adopted by similar utilities, or a standard established by a professional or standards organization such as the IEEE, IEC, ANSI, or NEMA.
4. ***Determine target performance levels***. These are targets that are appropriate and economically feasible. Target levels may be limited to specific customers or customer groups and may exceed the benchmark values.

Monitoring Considerations

Several common objectives of power quality monitoring are summarized here.

Monitoring to characterize system performance.

- This is the most general requirement.
- A power producer may find this objective important if it has the need to understand its system performance and then match that system performance with the needs of customers. System characterization is a proactive approach to power quality monitoring.
- By understanding the normal power quality performance of a system, a provider can quickly identify problems and can offer information to its customers to help them match their sensitive equipment's characteristics with realistic power quality characteristics.

Monitoring to characterize specific problems.

- Many power quality service departments or plant managers solve problems by performing short-term monitoring at specific customer sites or at difficult loads.
- This is a reactive mode of power quality monitoring, but it frequently identifies the cause of equipment incompatibility, which is the first step to a solution.

Monitoring as part of an enhanced power quality service.

- Many power producers are currently considering additional services to offer customers.
- One of these services would be to offer differentiated levels of power quality to match the needs of specific customers.
- Monitoring becomes essential to establish the benchmarks for the differentiated service and to verify that the utility achieves contracted levels of power quality

Monitoring as part of predictive or just-in-time maintenance.

- Power quality data gathered over time can be analyzed to provide information relating to specific equipment performance.
- For example, a repetitive arcing fault from an underground cable may signify impending cable failure, or repetitive capacitor-switching restrikes may signify impending failure on the capacitor-switching device.
- Equipment maintenance can be quickly ordered to avoid failure.

Choosing Monitoring Locations

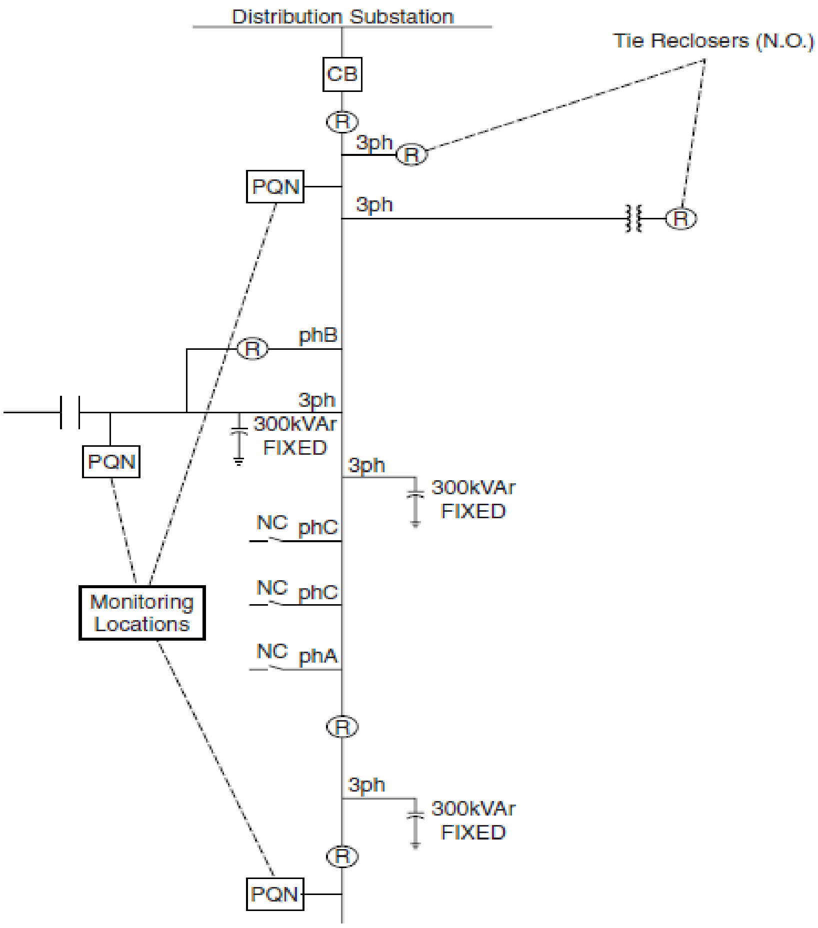

Fig 4.1 Typical distribution feeder monitoring scheme.

- It is very important that the monitoring locations be selected carefully based on the monitoring objectives.
- The monitoring experience gained from the EPRI DPQ project1 provides an excellent example of how to choose monitoring locations.
- The primary objective of the DPQ project was to characterize power quality on the U.S. electric utility distribution feeders.
- Actual feeder monitoring began in June 1992 and was completed in September 1995. Twenty four different utilities participated in the data-collection effort with almost 300 measurement sites.
- Monitoring for the project was designed to provide a statistically valid set of data of the various phenomena related to power quality. Since the primary objective was to characterize power quality on primary distribution feeders, monitoring was done on the actual feeder circuits.
- As shown in Fig above one monitor was located near the substation, and two additional sites were selected randomly.
- By randomly choosing the remote sites, the overall project results represented power quality on distribution feeders in general.
- When a monitoring project involves characterizing specific power quality problems that are actually being experienced by customers on the distribution system, the monitoring locations should be at actual customer service entrance locations because it includes the effect of step-down transformers supplying the customer.
- Data collected at the service entrance can also characterize the customer load

current variations and harmonic distortion levels.

- Monitoring at customer service entrance locations has the additional advantage of reduced transducer costs.
- In addition, it provides indications of the origin of the disturbances, i.e., the utility or the customer side of the meter.
- Another important aspect of the monitoring location when characterizing specific power quality problems is to locate the monitors as close as possible to the equipment affected by power quality variations.

Permanent Power Quality Monitoring Equipment

1. Digital fault recorders (DFRs).

- These may already be in place at many substations.
- A DFR will typically trigger on fault events and record the voltage and current waveforms that characterize the event.
- This makes them valuable for characterizing rms disturbances, such as voltage sags, during power system faults.
- DFRs also offer periodic waveform capture for calculating harmonic distortion levels.

2. Smart relays and other IEDs.

- Many types of substation equipment may have the capability to be an intelligent electronic device (IED) with monitoring capability.
- Manufacturers of devices like relays and reclosers that monitor the current anyway are adding on the capability to record disturbances and make the information available to an overall monitoring system controller.
- These devices can be located on the feeder circuits as well as at the substation.

3. Voltage recorders.

- Power providers use a variety of voltage recorders to monitor steady-state voltage variations on distribution systems. Typically, the voltage recorder provides information about the maximum, minimum, and average voltage within a specified sampling window (for example, 2 s).
- With this type of sampling, the recorder can characterize a voltage sag magnitude adequately. However, it will not provide the duration with a resolution less than 2 s.

4. In-plant power monitors.

- It is now common for monitoring systems in industrial facilities to have some power quality capabilities.
- Capabilities usually include waveshape capture for evaluation of harmonic distortion levels, voltage profiles for steady-state rms variations, and triggered waveshape captures for voltage sag conditions.

5. Special-purpose power quality monitors.

- The monitoring instrument developed for the EPRI DPQ project was specifically designed to measure the full range of power quality variations. This instrument features monitoring of voltage and current on all three phases plus the neutral.
- A14-bit analog-to-digital (A/D) board provides a sampling rate of 256 points per cycle for voltage and 128 points per cycle for current.
- This high sampling rate allowed detection of voltage harmonics as high as the 100th and current harmonics as high as the 50th.
- Power quality monitors are suitable for substations, feeder locations, and customer

service entrance locations.

6. Revenue meters.

- Revenue meters monitor the voltage and current anyway, so it seems logical to offer alternatives for more advanced monitoring that could include recording of power quality information.
- Virtually all the revenue meter manufacturers are moving in this direction, and the information from these meters can then be incorporated into an overall power quality monitoring system.

Historical Perspective of Power Quality Measuring Instruments

- Early monitoring devices were bulky, heavy boxes that required a screwdriver to make selections.
- Data collected were recorded on strip-chart paper.
- One of the earliest power quality monitoring instruments is a lightning strike recorder developed by General Electric in the 1920s.
- The instrument makes an impulse-like mark on strip-chart paper to record a lightning strike event along with its time and date of occurrence.
- The data were more qualitative then quantitative, making the data interpretation rather difficult.
- In 1960s,Martzloff developed a surge counter that could capture a voltage waveform of lightning strikes.
- The device consisted of a high persistence analog oscilloscope with a logarithmic sweep rate.
- The first generation of power quality monitors began in the mid-1970s when Dranetz Engineering Laboratories (now Dranetz-BMI) introduced the Series 606 power line disturbance analyzer.
- This was a microprocessor based monitor-analyzer first manufactured in 1975.
- The output of these monitors was text-based, printed on a paper tape.
- The printout described a disturbance by the event type (sag, interruption, etc.) and voltage magnitude.
- Second-generation power quality instruments debuted in the mid-1980s.
- This generation of power quality monitors generally featured full graphic display and digital memory to view and store captured power quality events, including both transients and steady-state events.
- By the mid-1990s, the third-generation power quality instruments emerged.
- The development of the third-generation power monitors was inspired in part by the EPRI DPQ project.

Some of the difficulties in managing a large system of power quality monitors:

1. Managing the large volume of raw measurement data that must be collected, analyzed, and archived becomes a serious challenge as the number of monitoring points grows.

2. The data volume collected at each monitoring point can strain communication mechanisms employed to move that data from monitor to analysis point.

3. As understanding of system performance grows through the feedback provided by the monitoring data, detailed views of certain events.

4. The real value of any monitoring system lies in its ability to generate information rather than in collecting and storing volumes of detailed raw data.

Power Quality Measurement Equipment

Types of instruments:

Basic categories of instruments that may be applicable include

■ Wiring and grounding test devices

■ Multimeters

■ Oscilloscopes

■ Disturbance analyzers

■ Harmonic analyzers and spectrum analyzers

■ Combination disturbance and harmonic analyzers

■ Flicker meters

■ Energy monitors

Some of the more important factors include

■ Number of channels (voltage and/or current)

■ Temperature specifications of the instrument

■ Ruggedness of the instrument

■ Input voltage range (e.g., 0 to 600 V)

■ Power requirements

■ Ability to measure three-phase voltages

■ Input isolation (isolation between input channels and from each input to ground)

■ Ability to measure currents

■ Housing of the instrument (portable, rack-mount, etc.)

■ Ease of use (user interface, graphics capability, etc.)

■ Documentation

■ Communication capability (modem, network interface)

■ Analysis software

Assessment of Power Quality Measurement Data

There are two streams of power quality data analysis, i.e., off-line and on-line analyses. The off-line power quality data analysis, as the term suggests, is performed off-line at the central processing locations. On the other hand, the on-line data analysis is performed within the instrument itself for immediate information dissemination.

Off-line power quality data assessment

- Off-line power quality data assessment is carried out separately from the monitoring instruments.
- Dedicated computer software is used for this purpose.
- The new standard format for interchanging power quality data—the Power Quality Data Interchange Format (PQDIF)—makes sharing of data between different types **of** monitoring systems much more feasible.

The off-line power quality data assessment software usually performs the following functions:

■ Viewing of individual disturbance events.

■ RMS variation analysis which includes tabulations of voltage sags and swells, magnitude-duration scatter plots based on CBEMA, ITI, or user-specified magnitude-duration curves, and computations of a wide range of rms indices such as SARFI, SIARFI, and CAIDI.

■ Steady-state analysis which includes trends of rms voltages, rms currents, and negativeand zero-sequence unbalances. Statistics can be temporally aggregated and dynamically filtered. Figures below show the time trend of phase A rms voltage along with its histogram representation

■ Harmonic analysis where users can perform voltage and current harmonic spectra, statistical analysis of various harmonic indices.

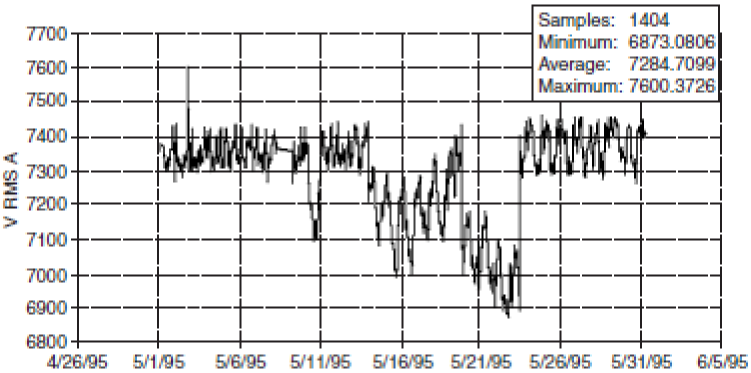

Fig 4.2 rms voltage variation in power quality analysis software program

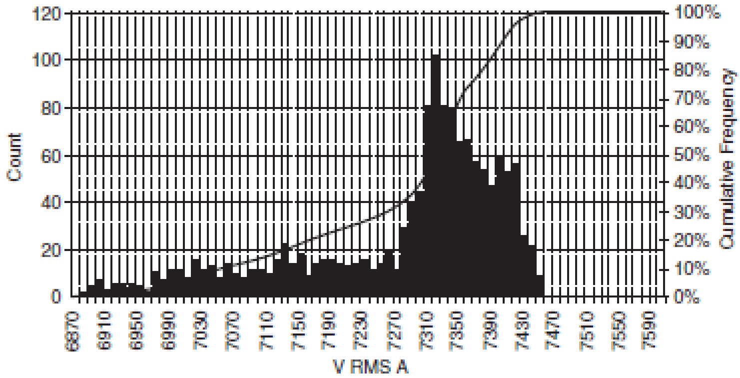

Fig 4.3 Histogram representation of rms voltage variation

■ Transient analysis which includes statistical analysis of maximum voltage, transient durations, and transient frequency.

■ Standardized power quality reports (e.g. daily reports, monthly reports, statistical performance reports, executive summaries, customer power quality summaries).

■ Analysis of protective device operation (identify problems).

■ Analysis of energy use.

■ Correlation of power quality levels or energy use with important parameters (e.g., voltage sag performance versus lightning flash density).

■ Equipment performance as a function of power quality levels (equipment sensitivity reports).

On-line power quality data

- On-line power quality data assessment analyzes data as they are captured.
- The analysis results are available immediately for rapid dissemination.
- Complexity in the software design requirement for on-line assessment is usually higher than that of off-line.
- One of the primary advantages of on-line data analysis is that it can provide instant message delivery to notify users of specific events of interest.
- Users can then take immediate actions upon receiving the notifications.

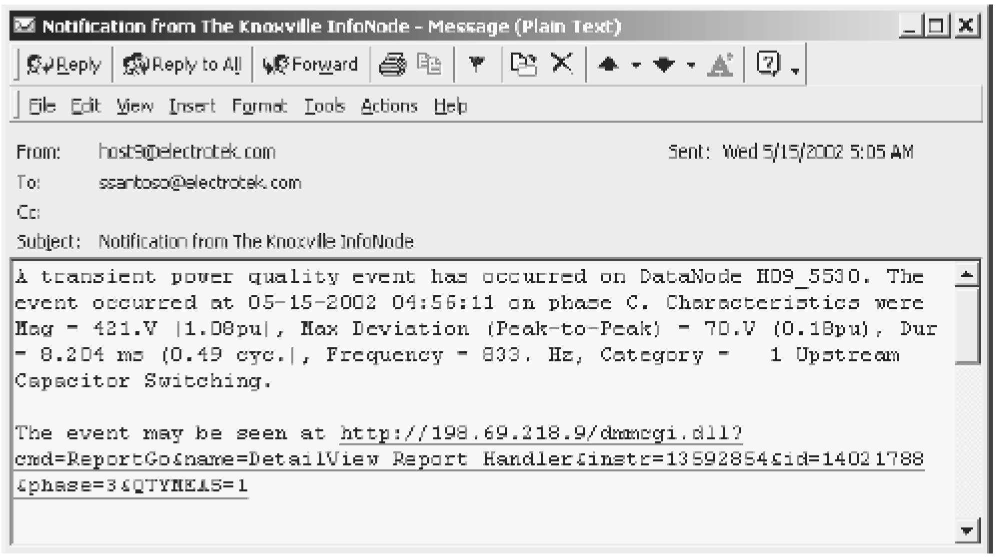

Fig 4.4 Example of sending email notifications to users about occurrence of PQ events

Figure above illustrates a simple message delivered to a user reporting that a capacitor bank located upstream from a data acquisition node called "Data Node H09_5530" was energized at 05-15-2002 at 04:56:11 A.M. The message also details the transient characteristics such as the magnitude, frequency, and duration along with the relative location of the capacitor bank from the data acquisition node.

Power Quality Monitoring Standards

Standards are very important in the area of power quality monitoring.

IEEE 1159 is the IEEE Working Group that coordinates the development of power quality monitoring standards.

(i) IEEE 1159: Guide for power quality monitoring IEEE Standard 1159 was developed to provide general guidelines for power quality measurements and to provide standard definitions for the different categories of power quality problems.

Three working groups were established.

The IEEE 1159.1 Working Group is developing guidelines for instrumentation requirements associated with different types of power quality phenomena. These requirements address issues like sampling rate requirements, synchronization, A/D sampling accuracy, and number of cycles to sample.

The IEEE 1159.2 Working Group is developing guidelines for characterizing different power quality phenomena. This includes definition of important characteristics that may relate to the impacts of the power quality variations (such as minimum magnitude, duration, phase shift, and number of phases for voltage sags).

The IEEE 1159.3 Working Group is defining an interchange format that can be used to exchange power quality monitoring information between different applications. IEEE developed the COMTRADE format for exchanging waveform data between fault recorders and other applications, such as relay testing equipment.

IEC 61000-4-30: Testing and Measurement Techniques—Power Quality Measurement Methods

IEC standards for monitoring power quality phenomena are provided in a series of documents with the numbers 61000-4-xx.

IEC 61000-4-7 provides the specifications for monitoring harmonic distortion levels.

IEC 61000-4-15 provides the specifications for monitoring flicker.

IEC (61000-4-30) is a new standard refers to the appropriate individual standards (like

61000-4-7 and 61000-4-15).
two classes of measurement equipment have been defined as per the procedures of IEC 61000-4-30:

- ■ Class A performance is for measurements where very precise accuracy is required. These instruments could be appropriate for laboratories or for special applications where highly precise results are required.
- ■ Class B performance still indicates that the recommended procedures for characterizing power quality variations are used but that the exact accuracy requirements may not be met. These instruments are appropriate for most system power quality monitoring (surveys, troubleshooting, characterizing performance, etc.)

Important Questions:

1. Explain significance of Power quality monitoring. List out power quality monitoring objectives.
2. Classify the types of PQ measurement equipment and explain any five of them.
3. Discuss how PQ monitoring data is assessed.
4. Discuss the following
(a) Multimeters
(b) Smart power quality monitors
(c) Flicker meter
(d) multimeters
5. Explain in detail about the equipment needed permanently for monitoring