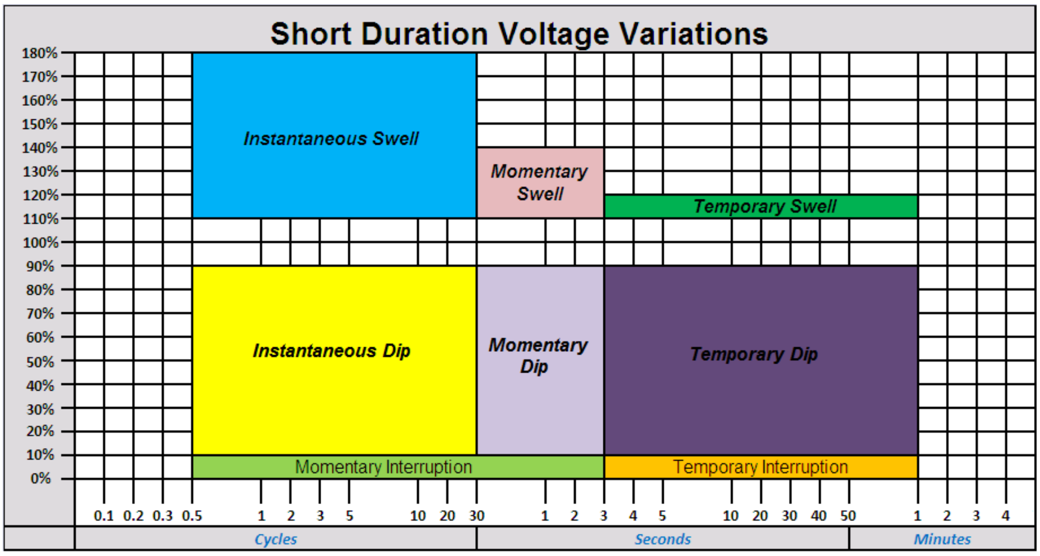
Common PQ Issues: Voltage Dips and Swells

Voltage dips and swells are two of the most common power quality events. Voltage dips and swells cannot be prevented on the power system. As impedances change during the course of a day, the voltage will momentarily change as well. The goal of power quality is to limit the number of dips and swells as well as the magnitude of these events such that they do not cause equipment malfunction or failure. The malfunction or failure of this equipment can cause large financial losses to various manufacturers. This paper will define the various types of voltage dips and swells that occur and the effect they have on various types of equipment. This paper shall also describe methodologies to measure and locate these events that cause equipment malfunction and failures.

Voltage dips and swells are defined in different manners based on their individual characteristics.



Instantaneous Dip is a short duration voltage variation that will last from 0.5 cycles to 30 cycles. The voltage during an instantaneous dip will vary from 10% to 90% of nominal.

An **interruption** is a short duration voltage variation that will last from 0.5 cycles to 3 seconds. The voltage during an interruption will fall to less than 10% of nominal.

Momentary Dip is a short duration voltage variation that will last from 30 cycles to 3 seconds. The voltage during a momentary dip will vary from 10% to 90% of nominal.

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A **temporary interruption** is a short duration voltage variation that will last from 3 seconds to 1 minute. The voltage during will fall to less than 10% of nominal.

Short duration voltage variations are typically caused by large loads that draw high inrush currents. These high inrush currents will cause the voltage to dip. Voltage Swells are typically due to large loads turning off. This causes a sudden change in load impedance which can cause the voltage to swell. These loads can include such things as large motors, arc furnaces and large welders. In addition, the switching of capacitor banks and network sections can also cause voltage dips and swells. Intermittent loose connections can also cause voltage dips and swells.

There are also events referred to as Long Duration Variations; these are voltage dips and swells that last for more than 1 minute. Voltage variation disturbances can cause equipment to malfunction such as computers locking up or data getting garbled. Breakers and arc lighting can trip; process equipment and commercial electronics may be tripped offline, and clocks may also be reset. These are just some examples of some of the problems that can be caused by voltage variations.

There are many types of Power Quality Analyzers such as the Megger MPQ-2000 that will allow operators to program various limits and perform high resolution recordings to capture these types of voltage variations. The challenge is how do we determine if the recorded voltage variation is causing the condition that the customer is reporting and how do we locate the root cause?

One of the tools available to help determine if a measured voltage variation is causing equipment to malfunction is the ITIC (CBEMA) Curve. This curve was published by the Information Technology Industry Council (formerly known as the Computer & Business Equipment

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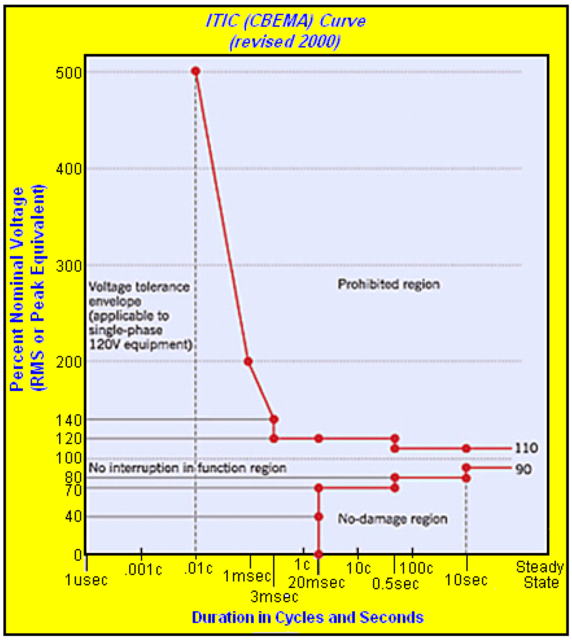
Manufacturer's Association). The ITIC (CBEMA) Curve describes an acceptable AC voltage window that can be tolerated by most Information Technology Equipment (ITE).



The ITIC (CBEMA) curve describes several ranges for voltage variation events. The voltage variation can be plotted on the graph as a point. The magnitude of the event as referenced to the nominal voltage is the X coordinate and the duration of the event in either cycles or seconds is the Y coordinate. Once the point is plotted it is easy to see if the event could be the cause of information technology equipment malfunction. (Computers, Faxes, routers, modems, internet, televisions...etc.)

Another type of curve is the SEMI F47 curve. This curve was developed by the industry association for the semiconductor industry known as Semiconductor Equipment and Materials International (SEMI) to place standards on semiconductor processing, metrology, and automated test equipment. The SEMI F47 curve defines a region of acceptable voltage variations on the AC power line of semiconductor processing equipment. The equipment should be able to tolerate voltage variations within this region. They must be able to tolerate dips to 50% of equipment

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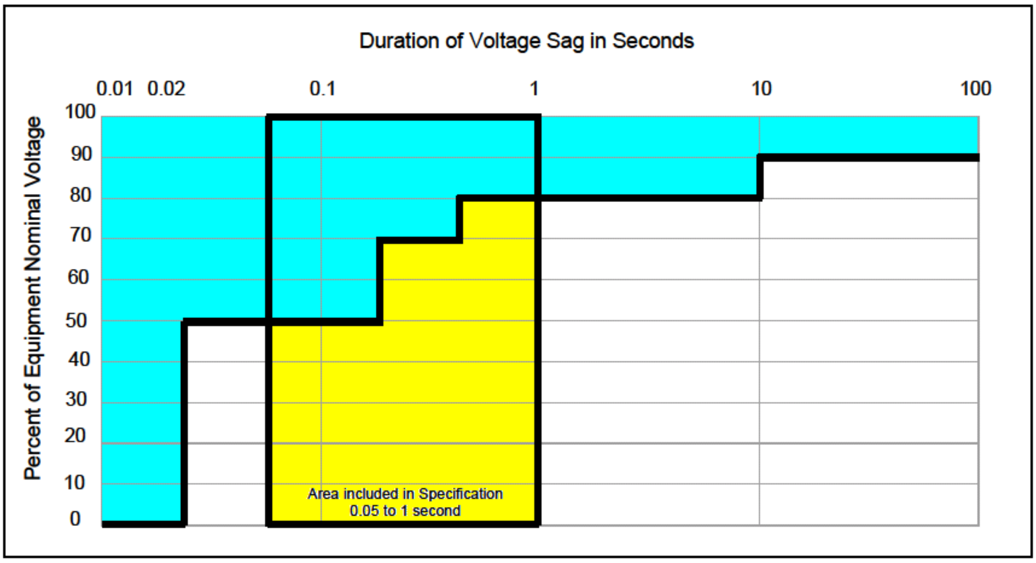
nominal voltage for durations of up to 200 ms as well as dips of 70% for up to 0.5 seconds, and dips of up to 80% for up to 1.0 second.



These types of curves can be a great asset in helping determine if a measured voltage variation is causing equipment to malfunction.

When reviewing recorded events it is also important to try to determine the direction the fault is coming from. The fault can either be coming from the load side or the source side. In order to determine this it is necessary to analyze the voltage magnitudes during the fault as well as the current magnitude that occurred during the fault.

When trying to determine the source of a voltage dip or swell, examine the minimum voltage recorded during the event against the maximum current recorded during the event.

If the current is in the opposite direction from the voltage then the event is coming from the load side. In the case of voltage dips, this would mean the current is swelling (opposite the voltage which is dipping). This means that there is a reduction in load impedance such as a large load turning on that is drawing an inrush current that is causing the voltage to dip. In the case of

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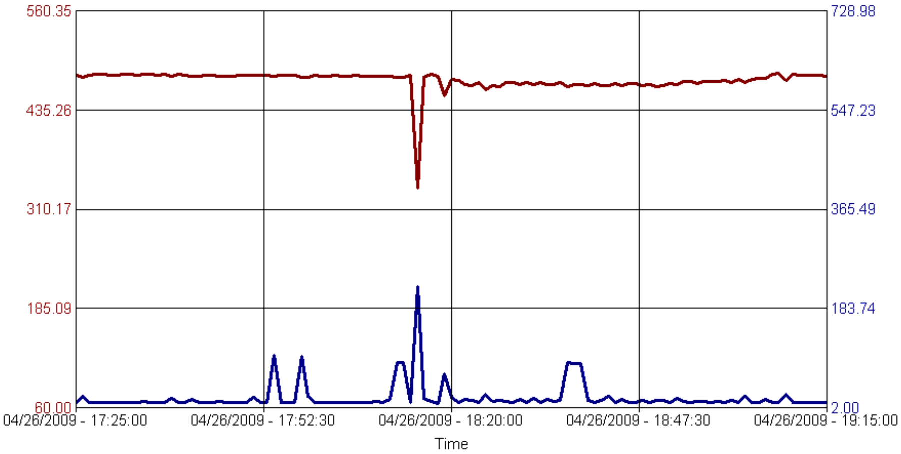
voltage swells this would mean the current is dipping (opposite the voltage which is swelling). This means that there has been an increase in load impedance such as a large load turning off that is causing the voltage to swell.



If the current is in the same direction as the voltage, then the event is coming from the source side. In the case of a voltage dip, this would mean the current is dipping (the same as the voltage which is dipping). This means that there has been a voltage reduction on the source side and the reduced difference of potential across the load has reduced the current. In the case of a voltage swell this would mean the current is swelling (the same as the voltage which is swelling). This means that there has been an increase in voltage on the source side and the increased difference of potential across the load has increased the current.

When problems are found that cause equipment malfunction or equipment failure there are several simple possibilities that should be examined before resorting to expensive conditioning equipment.

A common cause of voltage dips and swells is loose or poor connections. Before investing in conditioning equipment it is wise to check for loose or poor connections. Poor connections will have higher impedance, so they will have a larger voltage drop across them. A larger voltage drop

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across these connections will generate more heat. A quick way to search for poor connections is to look for this heat using an infra-red camera.

A common cause of equipment tripping offline is an incorrect nominal voltage being applied to that equipment. These incorrect voltages can include 230 volt equipment being fed from 208 volts or vice versa as well as 460 volt equipment being fed from 480 volts. Since incorrect nominal voltages are applied to the equipment, relatively small voltage variations could cause controllers to trip the equipment offline.

Note: Some 460-volt equipment has over-voltage, under-voltage and phase loss relays. When 460 volt equipment gets to 10% or about 506 volts it causes an over-voltage trip or alarm. A utility voltage can be at the upper limit of 504 volts and when a utility cap comes on the voltage may go to 508 for less than a cycle and cause an over-voltage trip.

In addition, the grounding methodology used can affect the performance of sensitive equipment.

In conclusion, the magnitude of voltage variations will be affected by the generation of power as well as its delivery and the load connected to it. When issues arise that cause the malfunction or failure of equipment, it is important to understand not only how to measure the disturbances but also how to determine if they are the cause of the malfunction and how to locate them.