Voltage Regulation

Application Note - AN-2

One of the most popular forms of power conditioning over the past 20 years has been the *Voltage Regulator*. The concept of voltage regulation is simple: monitor the level of voltage being fed to the sensitive load (usually the RMS voltage) and add or subtract voltage to achieve a desired output voltage.

A common source of confusion is with the terms Voltage Regulator and Power Conditioner. A *Power Conditioner* is any device that "conditions" the power. Power Conditioning may include voltage regulation, isolation, filtering, harmonic cancellation, transient suppression, or any combination of these. Modern power conditioners contain a minimum of isolation, filtering, and surge suppression.

Some voltage regulators are integrated into power conditioners, others provide only regulation. Many power conditioning topologies provide voltage regulation:

- Manual voltage taps
- Electro-mechanical voltage regulators (Motor-driven auto-transformer)
- Electronic tap-switching regulator
- Ferro-resonant voltage regulator
- Magnetic or Electronic waveform synthesizer

Benefits of Voltage Regulation

Voltage regulators were developed to provide a more stable source of voltage than the electric utility can provide. Low voltage can cause loss of function, over-heating, and erratic operation in some devices.

High voltage can cause over heating and component failure due to voltage stress. In either case, a voltage regulator would be used to provide voltage within the normal operating parameters of the sensitive load.

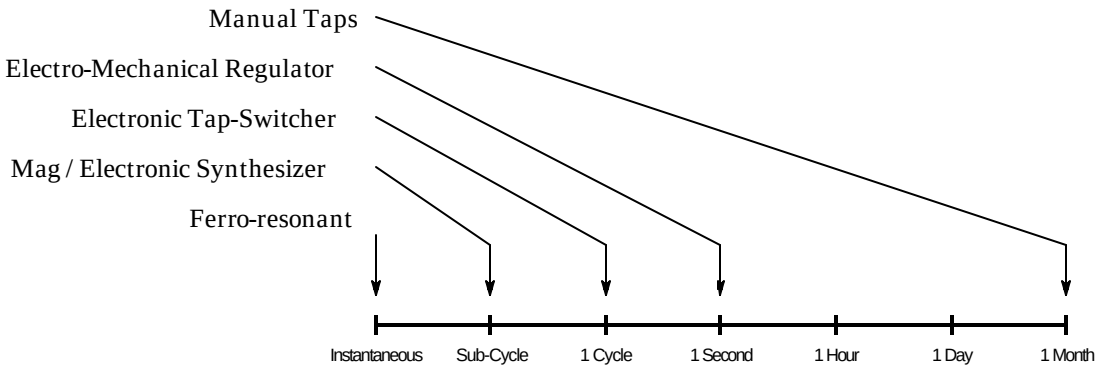
Voltage regulation problems can come in two forms: Short term problems, lasting for several cycles, are known as *Sags* and *Surges* (alternately *Dips* and *Swells*). Longer problems, lasting for several seconds to many hours, are known as *Low Voltage* (Brown-outs) and *High Voltage*.

Some voltage regulators with slow response times are only effective when dealing with longer fluctuations - the short Sags and Surges are over before the regulator can respond.

Other regulators have fast response times (instantaneous, or within a few cycles) making them suitable for both fast and slow voltage regulation problems.

Voltage Regulator Problems

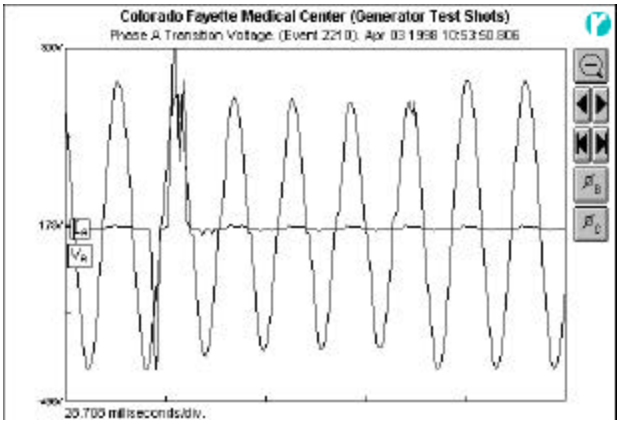
Voltage regulators are relatively simple devices, but they may *reduce* the reliability of an electrical system. In addition, the cost vs. benefit ratio of a voltage regulator is sometimes much higher than other power conditioning technologies. As a result, voltage regulators should be prescribed with care.



Efficiency: Some voltage regulators expend a lot of energy in order to operate. This affects the electrical cost-to-operate, and also increases the facility air conditioning load. At low power levels (such as a workstation) this may not be a problem, but at power levels above 1 kVA the efficiency becomes significant. Ferro-resonant and magnetic synthesizers in particular are very inefficient; while tap-switchers and electro-mechanical units may be quite efficient.

Reliability: Voltage regulators with active components are susceptible to failure rates much higher than transformers and other passive electronic components. Electro-mechanical regulators require regular maintenance for the motors, belts, and brushes that provide regulation. Tap-switching regulators contain large switching SCR's or Triacs that can fail due to line or load problems. Designers and end-users must factor in the cost to maintain and service a voltage regulator into the "cost of ownership" of such a device.

Load Interaction: Any voltage regulator may cause a load interaction, especially with sensitive equipment that contains pulsing loads. Examples of this type of equipment include industrial process machines, medical imaging equipment, and printing presses. When load interaction occurs, load changes or internal voltage regulation may cause the external voltage regulator to resonate or mis-operate. This actually causes voltage problems (sags and surges) on the output of the regulator that are not seen on the input.



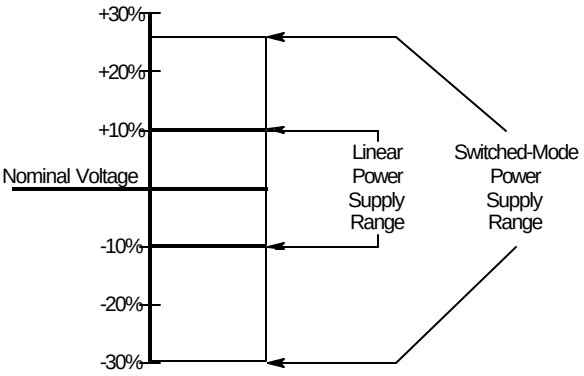
Load interaction caused this voltage "sag" - actually a voltage regulator misbehaving.

Load interaction is most common with tap-switching, magnetic synthesizer, or Ferro-resonant regulators. Unless the application has been approved by the manufacturer of the sensitive equipment that contains pulsing loads, such regulators should not be used.

Response to Severe Sag or Voltage Outage: Some regulators that contain electronic switching components will shut down or restart when they experience a severe voltage sag or outage. As a result, these devices could convert a short (1 cycle) disturbance into a several cycle outage. The sensitive load, which might ride-through a 1 cycle outage, will see the longer outage and shut down.

The Need for Voltage Regulation

The use of Voltage Regulators was widespread in the 1970's. At that time, most sensitive equipment was powered by *Linear Power Supplies*, that required a tightly regulated input voltage. In addition, electronic process equipment either had no internal voltage regulation, or very simple regulation that was affected by utility voltage changes. During this time, external voltage regulation often made a large improvement in system reliability and uptime.



However, in today's electronic world, the requirement for voltage regulation has dropped greatly, due to several factors. Linear Power Supplies have been largely replaced with *Switched Mode Power Supplies* (SMPS). These SMPS have a much higher dynamic range than the Linear Supplies, and can provide a regulated output voltage over a much greater input voltage range.

Modern industrial process equipment also contains substantial voltage regulation through the use of phase-controlled SCR's, switching power supplies, etc. As a result, the need for external voltage regulation has been eliminated in most areas. Only the most unstable electrical systems (such as found in developing countries), or older equipment designs have a need for voltage regulation.

Voltage Regulator Recommendations

In general, voltage regulators are not good *preventative measures* for ensuring power quality, for several reasons:

- High cost vs. benefit
- Possibility of Regulator interaction with load
- Poor Efficiency
- Reliability Concerns

Voltage regulators should be applied only if a chronic voltage problem has been demonstrated through experience or power monitoring.

The manufacturer of the sensitive equipment should be contacted to ensure that a particular voltage regulator will be compatible with the equipment.

Power conditioners without active voltage regulation (isolation transformer, filters, impulse suppression) provide cost-effective protection with none of the potential problems of voltage regulators. Such a device is an outstanding preventative measure that can be supplemented with voltage regulation when the need arises.

