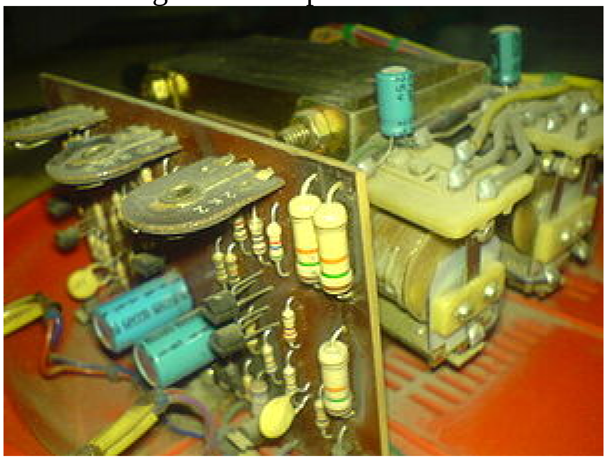
How to Regulate AC Voltages

Electromechanical regulators

Circuit design for a simple electromechanical voltage regulator.



Interior of an old electromechanical voltage regulator.

Graph of voltage output on a time scale.

In older electromechanical regulators, voltage regulation is easily accomplished by coiling the sensing wire to make an electromagnet. The magnetic field produced by the current attracts a moving ferrous core held back under spring tension or gravitational pull. As voltage increases, so does the current, strengthening the magnetic field produced by the coil and pulling the core towards the field. The magnet is physically connected to a mechanical power switch, which opens as the magnet moves into the field. As voltage decreases, so does the current, releasing spring tension or the weight of the core and causing it to retract. This closes the switch and allows the power to flow once more.

If the mechanical regulator design is sensitive to small voltage fluctuations, the motion of the solenoid core can be used to move a selector switch across a range of resistances or transformer windings to gradually step the output voltage up or down, or to rotate the position of a moving-coil AC regulator.

Early automobile generators and alternators had a mechanical voltage regulator using one, two, or three relays and various resistors to stabilize the generator's output at slightly more than 6 or 12 V, independent of the engine's rpm or the varying load on the vehicle's electrical system. Essentially, the relay(s) employed pulse width modulation to regulate the output of the generator, controlling the field current reaching the generator (or alternator) and in this way controlling the output voltage produced.

The regulators used for generators (but not alternators) also disconnect the generator when it was not producing electricity, thereby preventing the battery from discharging back into the generator and attempting to run it as a motor. The rectifier diodes in an alternator automatically perform this function so that a specific relay is not required; this appreciably simplified the regulator design.

More modern designs now use *solid state* technology (transistors) to perform the same function that the relays perform in electromechanical regulators.

Electromechanical regulators are used for mains voltage stabilisation—see Voltage regulator#AC voltage stabilizers below.

[edit] Coil-rotation AC voltage regulator

Basic design principle and circuit diagram for the rotating-coil AC voltage regulator.

This is an older type of regulator used in the 1920s that uses the principle of a fixed-position field coil and a second field coil that can be rotated on an axis in parallel with the fixed coil.

When the movable coil is positioned perpendicular to the fixed coil, the magnetic forces acting on the movable coil balance each other out and voltage output is unchanged. Rotating the coil in one direction or the other away from the center position will increase or decrease voltage in the secondary movable coil.

This type of regulator can be automated via a servo control mechanism to advance the movable coil position in order to provide voltage increase or decrease. A braking mechanism or high ratio gearing is used to hold the rotating coil in place against the powerful magnetic forces acting on the moving coil.

[edit] AC voltage stabilizers

Magnetic mains regulator

[edit] Electromechanical

Electromechanical regulators, usually called voltage stabilizers, have also been used to regulate the voltage on AC power distribution lines. These regulators operate by using a servomechanism to select the appropriate tap on an autotransformer with multiple taps, or by moving the wiper on a continuously variable autotransfomer. If the output voltage is not in the acceptable range, the servomechanism switches connections or moves the wiper to adjust the voltage into the acceptable region. The controls provide a deadband wherein the controller will not act, preventing the controller from constantly adjusting the voltage ("hunting") as it varies by an acceptably small amount.

[edit] Constant-voltage transformer

An alternative method is the use of a type of saturating transformer called a **ferroresonant transformer** or **constant-voltage transformer**. These transformers use a tank circuit composed of a high-voltage resonant winding and a capacitor to produce a nearly constant average output with a varying input. The ferroresonant approach is attractive due to its lack of active components, relying on the square loop saturation characteristics of the tank circuit to absorb variations in average input voltage. Older designs of ferroresonant transformers had an output with high harmonic content, leading to a distorted output waveform. Modern devices are used to construct a perfect sinewave. The ferroresonant action is a flux limiter rather than a voltage regulator, but with a fixed supply frequency it can maintain an almost constant average output voltage even as the input voltage varies widely.

The ferroresonant transformers, which are also known as Constant Voltage Transformers (CVTs) or ferros, are also good surge suppressors, as they provide high isolation and inherent short-circuit protection.

A ferroresonant transformer can operate with an input voltage range ±40% or more of the nominal voltage.

Output power factor remains in the range of 0.96 or higher from half to full load.

Because it regenerates an output voltage waveform, output distortion, which is typically less than 4%, is independent of any input voltage distortion, including notching.

Efficiency at full load is typically in the range of 89% to 93%. However, at low loads, efficiency can drop below 60% and no load losses can be as high as 20%. The current-limiting capability also becomes a handicap when a CVT is used in an application with moderate to high inrush current like motors, transformers or magnets. In this case, the CVT has to be sized to accommodate the peak current, thus forcing it to run at low loads and poor efficiency.

Minimum maintenance is required. Transformers and capacitors can be very reliable. Some units have included redundant capacitors to allow several capacitors to fail between inspections without any noticeable effect on the device's performance.

Output voltage varies about 1.2% for every 1% change in supply frequency. For example, a 2-Hz change in generator frequency, which is very large, results in an output voltage change of only 4%, which has little effect for most loads.

It accepts 100% single-phase switch-mode power supply loading without any requirement for derating, including all neutral components.

Input current distortion remains less than 8% THD even when supplying nonlinear loads with more than 100% current THD.

Drawbacks of CVTs (constant voltage transformers) are their larger size, audible humming sound, and high heat generation.

From http://en.wikipedia.org/wiki/Voltage_regulator#Constant-voltage_transformer