

# Voltage Regulators

## Technical Operation



### Regulators have two main Components:

#### 1. Power Handling System

- a. Motor driven variable transformers
- b. Buck-boost transformers

#### 2. Controller

(Microprocessor or Limited Range Control)

- a. Feedback
- b. Control
- c. Interface to variable transformer

### The Power Handling System

Line to neutral input power is applied across the motor-driven variable transformer (VT). The VT has a "center tap" at a point that coincides with the regulator's input range, and divides the VT into boosting and bucking areas.

The buck-boost transformer is a fixed ratio isolation transformer capable of high amperes at low voltage. The ratio of the buck-boost transformer is determined by the amount of voltage needed to boost or buck the input line voltage to the specified output level. The transformer is wired with its secondary in series with the phase line and the primary side of the buck-boost transformer connected across the "center tap" and the wiper of the variable transformer.

Depending on which side of the center tap the wiper is, the system will add to (boost) or subtract from (buck) the line voltage. The further the wiper is from the center tap the more bucking or boosting will occur.

The only active component in the main power path of the regulator is the secondary of the buck-boost transformers.

This gives the regulator the advantage of being able to withstand substantial current overloads. The variable transformer's brushes, which are the most vulnerable component in any variable voltage system, are isolated from this overload condition by the buck-boost transformer. Due to transformer inefficiency above rated design, the amount of current the buck-boost transformer can induce across the transformer is dramatically decreased as the overload current increases.

The regulator's magnetic components are sized based on the correcting range. This is important when powering nonlinear loads. If an all variable transformer system was used, the amount of magnetic losses due to harmonic content would be reflected by 100% of the regulator's rating.

In a single line control (SLC) regulator, one phase is selected to represent a control feedback for all three phases. All three phases of the variable transformer's wipers are controlled by one motor, and all three phases will be changed at the same time by the same amount.

In an individual phase control (IPC) regulator, each phase has a separate control feedback. Since a separate motor controls each variable transformer's wiper each phase will change independently of the other phases.

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## The Controller

### MP Controller (Microprocessor Controller) Used on MVR and MLC Units

The MP Controller is a panel mounted Staco Energy MPC2T series controller. It is comprised of:

- Three independent voltage reading circuits
- Three 120 volt motor drive interfaces
- A 16 bit analog to digital converter
- A microprocessor with custom control software
- TTL high/low alarm outputs
- A local display terminal with a numeric keypad
- An RS-232 communications port

Each voltage reading circuit conditions the AC feedback circuit by stepping down the high level AC signal with a small potential transformer. A true RMS AC to DC converter further processes this low level signal. The output of the true RMS converter is amplified and multiplexed into the 16-bit A/D converter. Each feedback channel is read for every electrical cycle and the resultant digitized voltage level is placed in the processor's memory register.

The processor to control the motor drive interfaces by comparing the digitized voltage level to the customer set voltage level. The control algorithm used by the controller has two set point deadbands. The close deadband is set using dip switches located on the main processor board. Output ranges of +/-0.5, 1, 2, and 4 volt for the selected nominal output. The second wider band is a function of the smaller band and is calculated by the processor. When the feedback voltage is outside of the wider control band, the corresponding motor is driven toward the set-point at full motor speed. When the feedback is with the wide band but still outside of the close band, the processor generates a modulated pulse width signal that slows the motor. When the feedback is within the close band, all motor movement is stopped. This slowing allows the regulator to correct to the desired output without overshooting the set-point, thus preventing oscillations during minor corrections, while larger corrections can be made in the least amount of time.

The 120 volt motor driver interface has the processor's TTL central information optically coupled to a set of 120 volt AC triacs. These signals are used by the regulator's synchronous motors to increase or decrease the input voltage to match output requirements.

The use of the local display terminal, high/low limits and the RS-232 interface is covered in the publication, "User's Handbook for MP Series Controller" (003-1622).

The controller is also available as a signal line controller with one channel of feedback and motor control.

### LRC Controller (Solid State) Used on AVR and PLC Units

This limited range controller utilizes discrete components for feedback voltage monitoring and motor control. IRCs are used as standard controllers on single line controllers (SLC). The controller uses a half-wave peak detect conditioning circuit for AC feedback monitoring and an optically isolated triac for 120 volt motor control.

Using the front panel potentiometer enters the output voltage set-point. The resultant signal is compared to the feedback signal to determine drive commands for the motor interface circuit. A second sensitivity pot located on the front control panel controls deadband for the system.

## Voltage Regulator and Power Conditioner Design

Staco Energy Products Automatic Voltage Regulators (AVR) are reliable and dependable for all types of industrial, broadcast, marine and commercial applications.

The core of the Staco Voltage Regulator consists of a motorized variable transformer in unison with a buck-boost fixed ratio transformer.

The variable transformer is designed according to its rated current as well as maximum current. The maximum current can be drawn from the transformer only when the output voltage is set near the line voltage. Rated current can be drawn at any setting of the transformer and is the only rating applicable when the overvoltage connection of the unit is employed.

The two ratings exist because there are two basic categories of load (linear and nonlinear), and because the unit cannot supply as much current at a mid-range as it can near the extremes without overheating. In a typical constant-impedance load, the maximum current is drawn at maximum voltage and permits greater performance.

An example of this is a 175 amp load: the regulator distributes the load through five coils, each carrying 35 amps. Adding more coils can reduce current in each coil. Adding three more coils, for a total of eight, reduces the current in each coil to 21.9 amps, resulting in an increase in the transformer's brush life, as well as the life of the coils.

Staco Variable Transformers have the capacity to handle non-repetitive short duration overload currents. Depending on the size of the coil used in its construction, 500% overload conditions for short periods of time are acceptable.

The Staco Variable Transformer is inherently a wide-range device. Output power is selected by sliding a carbon brush across the windings of the transformer. Output power may be held constant for a given load when the input supply voltage changes by simply changing the output to match the change in the input. Automating the transformer with a motor can do this. The motor drives the brush up or down the winding, increasing or decreasing the output, as the input increases or decreases.

Until now, only Staco Energy's Variable Transformer capacity to supply output power sufficient to meet load demands have been used. This total discussion assumes constant input supply voltage. If however, input supply voltage varies, the Staco Variable Transformer, in conjunction with a buck-boost transformer is the applicable design. The Staco Automatic Voltage Regulator will sense the output and compare it to the input. The output can be held constant with standard or custom input ranges of +10% -15%; +/- 15%; +10% -20%; etc.

The buck-boost fixed ratio transformer has two positive effects. First, the transformer is the initial step in regulation, resulting in a selectable range of desired output voltages. The variable transformer's selectable range is from 0-117% of the supplied voltage. However, this may not be a useful range, and only a portion of that range is desired. The buck-boost transformer will either buck or boost the voltage output of the variable, thus narrowing the selectable output range.



Second, the buck-boost transformer reduces the work the variable transformer must perform. The buck-boost multiplies the power rating of the transformer. The buck-boost reduces the current per coil requirement of the variable transformer. As discussed earlier, reduced current per coil results in increased life of the brushes and coils.

The Automatic Voltage Regulator has considerable flexibility. It can be designed for multiple voltages (120 Vac to 600 Vac); multiple frequencies (47 to 63Hz); single and three phase, single or individual phase controlled, 2kVA to 1500 kVA; digital or analog meters; with or without circuit breakers, maintenance bypass switches, weatherproof enclosures, Delta or WYE in put source, transient suppression and rack-mounting.

Staco Energy's AVRs and power conditioners now have the option to be programmed or communication linked to intelligent equipment. This is a standard on all individual phase controlled units.

The integration of Staco Energy's MP Series Microprocessor gives new flexibility for voltage control. The MP Microprocessor can be computer linked through RS-232, RS-422, or IEEE488. The output of the regulator or power conditioner will be microprocessor controlled to automatically regulate the output voltage to within a control band of +/-0.5 to 4 volts.

The MP Controller also allows customers to set high/low limits for each phase on the regulator. Through an interface, these limits can be used to operate High/Low Limit LEDs, etc.

A phase loss option in the MP controller could intelligently control a power device like a contractor to shut off power when one or more phases of the supply power drops below the low limit set point. The controller will monitor the voltage, and when it is within a customer selected deadband, the unit will resume normal operation.

Other options include double-shielded isolation transformer and transient suppression, thus making the AVR a voltage conditioner, called a PLC-Power line Conditioner. Now the AVR can be mode intelligent. The MP Series controller links the Staco AVR to your computer. The MP Series Controller increases output voltage regulation to +/-0.5 volts.

Units with the MP Controller installed will have product numbers starting with MVR and MIC, depending on their power conditioning capabilities.

## Staco Stepper Drive Controller

Staco Energy's Stepper Motor Controller for variable voltage autotransformers uses a microprocessor chip to control the output voltage level of an autotransformer by comparing a conditioned output voltage signal from the variable transformer with a set point voltage signal and repositions the transformers pickup brush using a stepper motor drive to provide the desired voltage output.

The unit has an on-board pulse-width modulated switch-mode regulated power supply for the signal conditioning circuits, the digital control circuits and the stepper motor power. AC power for the supplies is derived from voltage taps on the autotransformer.

The unit applies an AC feedback signal across a high-impedance voltage divider. The AC signal is then conditioned, rectified, and placed across a capacitor based sampling circuit that is controlled by the microprocessor chip. The resultant DC signal is then conditioned by an amplifier and either offset by a resistor amplifier network or fed directly into the A/D port of the microprocessor chip. This function is jumper selectable, with a set point signal of 0-5 VDC. The controller chip is an 8-bit CMOS microcontroller with an A/D converter programmed with a Staco Energy developed control algorithm.

The feedback signal is then compared to the set point signal in the controller chip where an appropriate four-line output pulse signal is generated. The output signal may be altered based on additional digital input signals from high/low limit switches. The four lines of output pulse are fed into a stepper driver signal conditioning chip and then to a stepper drive motor, which has been directly coupled to the variable transformer's pickup brush.

When the conditioned feedback signal matches the set point signal, there is no movement of the brush pickup.

Feedback signals and power supply inputs are protected by on-board self-resetting fuses.

## Voltage Regulation Products

Voltage Regulator: A system consisting of a motorized variable autotransformer, buck-boost transformer, closed loop feedback, and control circuitry to maintain a precise output voltage.

The Staco Voltage Regulator is an electromechanical unit.

### Features:

- Single or Three Phase
- Complete Family Rating: 2.5 to 1500 kVA
- Tight Regulation: +/-0.25% to 1.0%
- High Efficiency (Low BTU): 99%
- No Waveform Distortion
- No Added Harmonics
- No Power Factor Restrictions
- Buck-Boost Design
- High Reliability
- Low Maintenance
- 100% Front Accessible NEMA-I Enclosure
- Extremely Low Impedance
- Insensitive to Frequency Changes

### Options:

- Individual Phase Control
- Analog or Digital Meter
- Phase Reversal Protection
- Input Circuit Breaker
- Microprocessor Controller:
  - true RMS
  - voltage sensing
  - high/low limit set points
  - digital output voltmeter
  - modem compatible
  - phase loss detection
  - logic level signal

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## About Staco Energy Products

*Since 1937, customers worldwide have been relying on Staco Energy Products Company to deliver voltage control and power quality solutions tailored to their needs.*

*As a leading power quality resource, we offer our customers world-class support; from our thorough applications assessment, to our ability to design and deliver a solution that is tailored to the specific needs of our customers; through delivery and commissioning.*

*Our professional, factory trained service team is in place to ensure that our customers' revenues are protected, and their investment provides them with many years of trouble free operation.*

*Staco develops total power solutions for OEM and end user applications.*



Your tailored power solutions provider

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