



The AVR voltage regulator and PLC power conditioner product lines consists of over 250 standard units arranged in 29 different voltage families to provide 95% coverage of day-to-day application needs. For ease of application, all units have been kVA rated per the Electrical Industry Equipment Standards for secondary distribution systems. All units are designed to provide $\pm 1\%$ or better output voltage regulation over the entire input voltage range. The complete offering of AVR and PLC products is of a modular design, designed to provide 100% front accessibility for ease of installation, and is enclosed in an indoor ventilated drip-proof enclosure.

The modular PLC power conditioner consists of a standard AVR, a double shielded output isolation transformer, and a transient voltage suppression package, all enclosed in a single modular enclosure. The type "MP" microprocessor controller is standard on all individual phase controlled (IPC) voltage regulators and power conditioners and is offered as an option on all other units. An external bypass, enclosed in its own indoor ventilated drip-proof enclosure, is available as an option to provide both electrical and mechanical isolation from the regulator or power conditioner for ease of scheduled preventive maintenance.

TYPICAL APPLICATIONS

- **BROADCAST:** Regulation for Radio and TV station transmitters, receivers, and mobile production vehicles.
- **COMMERCIAL:** High rise building whole floor regulation or power conditioning, input voltage regulation for elevator control and large A/C chillers.

- **INDUSTRIAL:** Process center power quality improvement, standard or customized test stands for product quality testing or design verification.
- **MARINE:** Dockside or shipboard voltage regulation and power conditioning.
- **MEDICAL:** X-Ray, CAT scan, and MRI power conditioning.

PRODUCT FEATURES

- **RATING:** 2.5 to 1500 kVA arranged in 29 single and three phase voltage families.
- **INPUT:** Wide range +10%, -20% with standard Delta/Delta, Delta/Wye, and Wye/Wye three phase designs.
- **OUTPUT:** $\pm 1\%$ regulation with no wave form distortion.
- **EFFICIENCY:** Low impedance design with a typical efficiency of 99%.
- **OVERLOAD:** 50% one hour, 1000% 30 cycles.
- **HARMONICS:** None added to system.
- **POWER FACTOR LOAD RESTRICTIONS:** None
- **MODULAR DESIGN**
- **ENCLOSURE:** Indoor ventilated drip-proof
- **100% FRONT ACCESSIBILITY**
- **EXTERNAL BYPASS SWITCH**
- **COMMUNICATIONS:** RS-232, RS-422, IEEE-488
- **POWER CONDITIONERS:** Isolation output transformer and voltage suppression package.

Electrical system concerns

- ENERGY EFFICIENCY
- POWER QUALITY
 - VOLTAGE FLUCTUATIONS
 - ODD HARMONICS
 - ELECTRICAL NOISE
 - BROWNOUTS

In today's world, the cost of electrical power and its quality have become major operating concerns. The continuing increase in the cost of electrical power has heighten interest in energy savings and poor power quality has been indentified as a cause of malfunctions and expensive shutdowns in new high technology equipment.

The chart below shows some of the causes and the effects of poor power quality. Filter networks, surge suppressors, and isolation transformers can solve many of the power quality problems that occur, but each can involve system tradeoffs if applied as a stand alone solution. Filter networks tend to be tuned to an existing load condition and if the load changes the engineered network may become ineffective. Surge suppressors shunt voltage transients to ground possibly transforming a line voltage problem into a ground potential problem. Shielded isolation transformers can provide electrical noise attenuation, but like filters and suppressors do not offer protection against voltage fluctuations and brownouts.

However, when surge suppressors and isolation transformers are coupled with a voltage regulator, like Staco's PLC, the combination can provide an excellent solution to these power quality problems.

FOUR TYPES OF REGULATORS

There are four main types of regulators offered in today's market ... Ferroresonant , Tap Switching, Limited Range Variable Transformer, and Variable Transformer Buck-Boost.

FERRORESONANT

Ferroresonant constant voltage transformers use a capacitor in series with the transformer coil and tend to be high impedance devices that are sensitive to load changes and do not handle high inrush loads very well. They can interact with switch mode power supplies to produce transients and electrical noise on the output and their resonant circuits make them particularly sensitive to frequency changes. When applied cautiously these units can provide 2 to 5% output regulation, load isolation, and noise attenuation.

TAP SWITCHING TRANSFORMER

Tap switching transformer based regulators monitor output voltage and then use solid-state switching circuits for changing the transformer taps on a fixed ratio transformer. These units tend to provide only 3 to 5% output regulation as the number of taps used are minimized to control cost. Although these regulators are extremely fast, this fast response time can often create instability when powering equipment with switch mode power supplies and their output waveform tends to produce harmonics and radio frequency interference.

POWER QUALITY PROBLEMS • CAUSES AND EFFECTS

POWER PROBLEM	POSSIBLE CAUSES	EFFECTS
Voltage Fluctuations (Surges, Sags, Spikes)	Overburdened distribution system; Heavy equipment startup; Lightning; Utility grid switching; Unstable generators	System lock-up; Data loss; Control loss; Power supply damage; Lighting flicker
Odd Harmonics	Switch-mode power supplies; Nonlinear loads	High neutral currents; Circuit breaker nuisance tripping; Motor overheating; Transformer overheating
Electrical Noise	Switching devices; Motorized equipment; Improper grounding; Arc welders; Electronic equipment	Data corruption; Timing signal variations; Erroneous command functions; Servo control instability; Changes in processing states
Brownouts	Power line faults; Planned and unplanned utility voltage reduction	Motor overheating; Low lamp output; Reduced equipment performance; System shutdown; Transformer overheating; Data corruption and loss

LIMITED RANGE VARIABLE TRANSFORMER

Limited range variable transformer regulators use variable transformers to directly control the output voltage of the regulator. This places the variable transformer's vulnerable brush and brush track directly in the power path of the regulator subjecting these critical components to system stresses which can lead to possible premature regulator failure. Applications with high overload cycling might require the unit to be oversized and with the variable transformer brushes in the power path, electrical noise can be introduced into the system. While limited range variable transformer regulators can provide ± 1 to 3% output voltage regulation they tend to be larger than the Variable Transformer Buck-Boost Regulator as manufactured by Staco that offer $\pm 1\%$ output regulation.

STACO BUCK-BOOST VOLTAGE REGULATORS SINGLE PHASE REGULATORS

Staco voltage regulators consist of three basic components: a motorized variable transformer, a buck-boost transformer, and a controller.

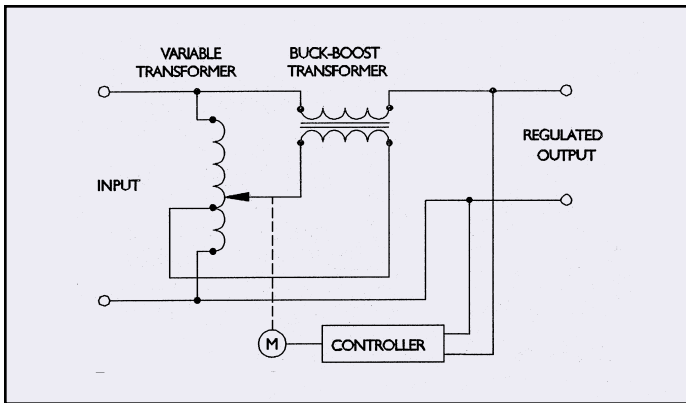


Figure 1. Single Phase Regulator Block Diagram

Input power is applied across the motor driven variable transformer which has a "center tap" that divides the variable transformer into bucking and boosting voltage 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 buck or boost the input line voltage to maintain the specified output level. The buck-boost transformer secondary is wired in series with the load and the primary is connected across the variable transformer's "center tap" and brush terminals. Depending on which side of the "center tap" the variable transformer brush is positioned, the variable/buck-boost transformer system will add to (boost) or subtract from (buck) the input line voltage. The further the variable transformer brush is from the "center tap" the more bucking or boosting of voltage will occur.

The key to the proven reliability and long trouble free service life of a Staco Voltage Regulator is in the combination of a motor driven variable transformer with buck-boost transformer technology.

As shown in figure 1, the only active component in the main power path of the voltage regulator is the secondary of the buck-boost transformer. This gives the Staco regulator the advantage of being able to withstand substantial current overloads. The variable transformer brushes, which are the most vulnerable component in any variable transformer system, are completely isolated from overload conditions by the buck-boost transformer. Due to transformer inefficiency above rated design, the amount of current that the buck-boost transformer can induce across to its primary winding and into the variable transformer circuit is dramatically decreased as regulator overload current increases.

The controller monitors the regulator's output voltage and then uses these feedback signals to determine drive commands for the variable transformer motor interface circuit. The controller is designed to adjust the motorized variable transformer to provide a $\pm 1\%$ or better output voltage regulation over the entire input voltage range.

Staco offers two types of controllers. The solid state type LRC controller is standard on type AVR regulators and the micro-processor type MP controller which is offered as standard on all MVR voltage regulators and is available as an option for AVR units.

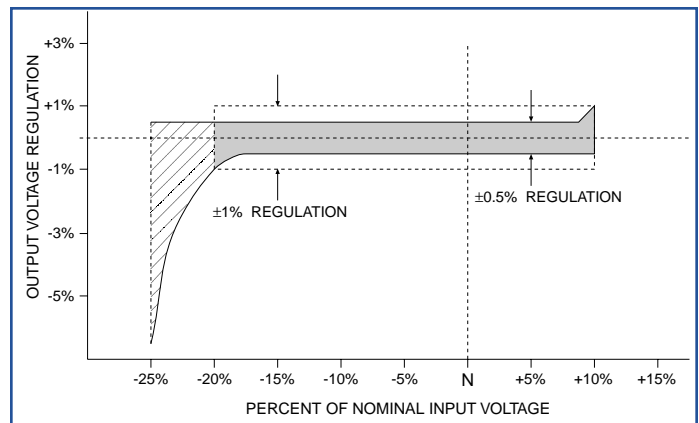


Figure 2. Output Voltage Regulation vs Input Range

Type of Controller	Input Range	Output Regulation	Typical Units
LRC	+9% to -19%	$\pm 0.5\%$	AVR or PLC
	+9% to -10%, -19% to -20%	$\pm 1\%$	
MP	+9% to -19%	± 0.5 VAC	MVR or MLC
	+9% to +10%, -19% to -20%	$\pm 1\%$	

While Staco voltage regulators are designed to provide a maximum output voltage regulation of $\pm 1\%$ with an input voltage range of +10% to -20%, the chart in figure 2 shows the actual regulation curve of a typical Staco voltage regulator. Over an input voltage range of +9% to -19%, the typical Staco regulator will maintain an output regulation of $\pm 0.5\%$.

THREE PHASE REGULATORS

Figure 3 illustrates a block diagram for a three phase voltage regulator. There are still only three basic components, but in a three phase configuration, each phase has its own variable transformer and buck-boost transformer. The three variable transformers are driven by a single motor in what is called a single line control (SLC) configuration.

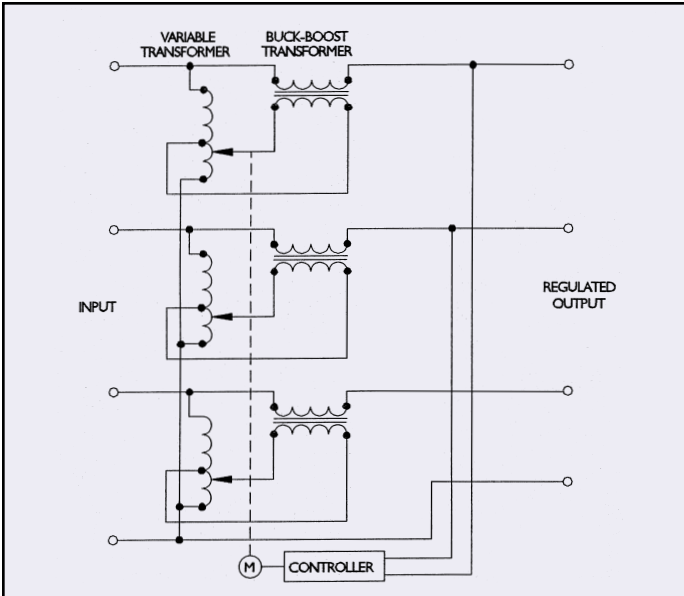


Figure 3. Three Phase Regulator Block Diagram

In figure 3, one phase of the regulator is selected to represent the control feedback for all three phases. The variable transformer in each phase is driven by the single motor and thus the variable transformer brushes in each unit will move by the same amount, in the same direction, and at the same time.

Staco also offers an individual phase control (IPC) voltage regulator design. In an individual phase controlled unit each output phase has its own controller monitored voltage feedback loop, each variable transformer is driven by its own motor, and each output phase is regulated independently of the other phases. Single line control is the design choice for single phase regulators and in three phase regulators for balanced load applications. An individual phase controlled regulator is an excellent design choice for three phase distributed load applications, consisting of both single and three phase loads, as the regulator will provide a regulated and balanced output voltage even under unbalanced line and load conditions.

Complete schematic diagrams covering single and three phase single line controlled and three phase individual phased controlled units may be found on page 9.

STACO CONTROLLERS

THE LRC CONTROLLER

The type LRC controller is the standard controller for both single and three phase single line control (SLC) voltage regulators.



Figure 4. LRC Control Panel

The LRC, limited range controller, utilizes discrete components for feedback voltage monitoring and motor control. The controller uses a half-wave peak detection and conditioning circuit for AC feedback monitoring and an optically isolated triac for 120 volt motor control. The output voltage setpoint is entered through the front panel potentiometer. The resultant signal is compared to the feedback signal to determine drive commands for the motor interface circuit. A second potentiometer on the front panel provides for system deadband and sensitivity control.

THE MP MICROPROCESSOR CONTROLLER

The type MP, microprocessor controller, offers users new flexibility in the control of the regulated output voltage.



Figure 5. MP Control Panel

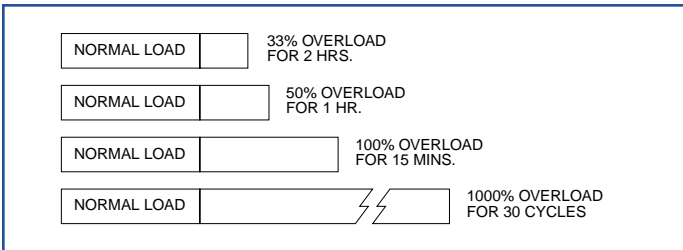
This intelligent microprocessor based controller is capable of operating in several different modes which can be programmed locally with the panel mounted microterminal or remotely through a RS-232, RS-422, or IEEE-488 bi-directional communication port. The panel mounted microterminal has a LCD display for display of output voltages and setpoints. Multiple set points may be programmed for variable speed, ramping, and variable dwell. The AC feedback signal may be configured to be compatible to the output voltage. It can be user programmed to accept peak to peak, average, or RMS measurements. The MP controller is standard on all three phase individual phase controlled (IPC) MVR regulators and is available as an option on all single and three phase AVR regulators.

WHY CHOOSE A STACO REGULATOR or POWER CONDITIONER...*The STACO-PLUS*

Staco has been in the AC voltage control and regulation field since 1937. Today, Staco's products reflect this experience. Staco regulators are built for long-term reliability and trouble free operation. High quality components, optimum design, and excellent workmanship go together to ensure many years of satisfactory performance.

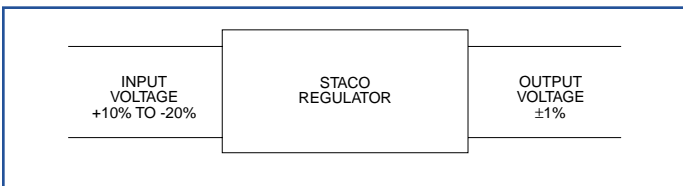
Conservative Ratings

Staco regulators are designed to withstand substantial current overloads.



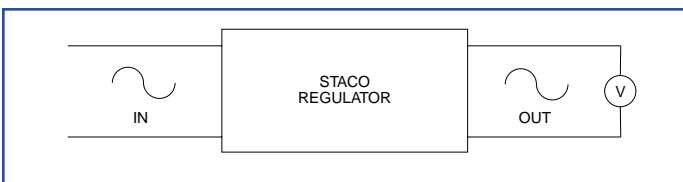
Accuracy

Staco regulators will maintain a constant output voltage within $\pm 1\%$ or better, regardless of input voltage variations from $+10\%$ to -20% of the nominal input value in standard models. If the supply voltage varies beyond the regulating range, the regulator continues to provide its maximum correction so that the output voltage varies only by the amount that the line voltage deviates beyond the regulating limits. The usefulness of this feature is best illustrated by a motor load which can operate satisfactorily on a supply voltage of 20% below nominal; using a Staco regulator, the same motor can be operated when the line voltage falls to 39% below nominal.



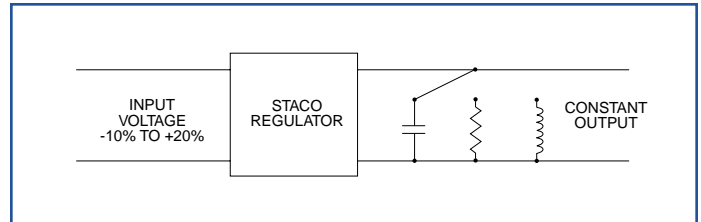
No Waveform Distortion— No Harmonics Added

Staco regulators, unlike some types of regulators, cause no waveform distortion and add no harmonics to the system. They do not introduce awkward and irritating errors in voltage and current measurement which may occur if the normal wave shape of the supply voltage is distorted.



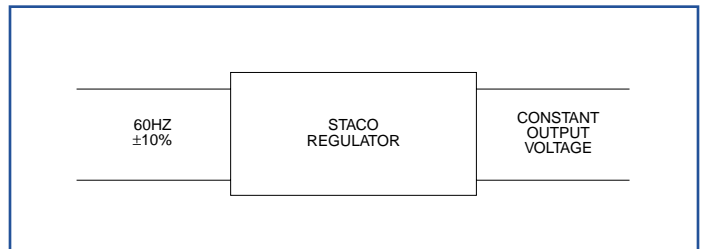
Independent of Power Factor

Staco regulators perform equally well whether the connected load is capacitive, resistive, or inductive in nature.



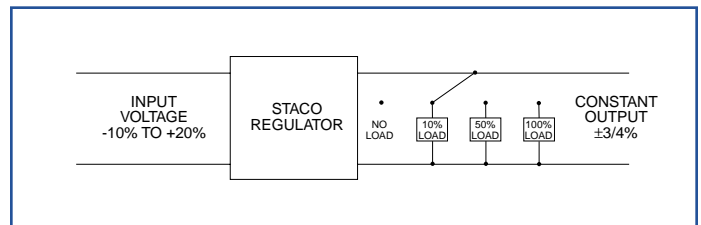
Insensitive to Frequency Changes

Staco manufactures regulators which will accept line frequency changes of up to $\pm 10\%$ without loss of output regulation.



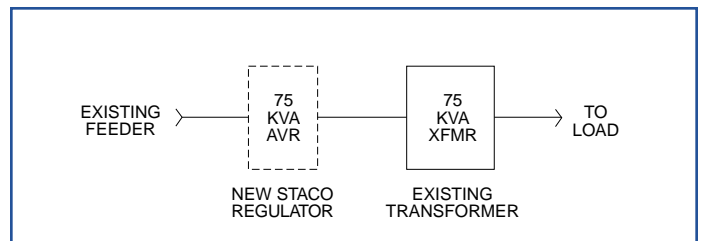
Compensates for Load Changes

Staco regulators maintain a constant output voltage regardless of load current changes from zero to full rated load.



Rated per Industry Standards

Staco regulators are designed and rated to meet standard industry kVA ratings for application ease in both new and existing installations. No longer is there a need to oversize the regulator to be able to utilize the full capability of a feeder circuit.



VOLTAGE REGULATOR and POWER CONDITIONER OPTIONS

EXTERNAL BYPASS SWITCH



The external bypass switch option is a mechanically interlocked three position "On", "Off", "Bypass" non-load break switch. Units are 600 volt class, 50/60 Hz rated. The bypass switch is enclosed in an indoor ventilated drip-proof enclosure with the operating handle located behind a removable front cover to limit unauthorized accessibility. Cable terminations are provided for system input, load output, plus AVR/PLC input and output. The external bypass switch is designed to provide complete electrical and mechanical isolation from the voltage regulator or power conditioner it controls. Dimensions may be found on page 19.

MICROPROCESSOR CONTROLLER



The type MP controller option offers an intelligent control that provides user control and monitoring locally through a panel mounted microterminal or remotely through its bi-directional communications port. The MP controller is user configurable to accept peak-to-peak, RMS, or average voltage feedback signals and provides for set point and dead-band adjustment. The MP controller is standard on individual phase controlled three phase MVR regulators, MLC power conditioners, and is available as an option on all other units. For additional information on the MP controller refer to the "MP Series Controllers", catalog 004-5007.

Phase	Amp Rating	Catalog Number	Ship Weight (lbs)
Single Phase *	65	MB-S65	30
	100	MB-S100	40
	200	MB-S200	70
Three Phase	65	MB-T65	140
	100	MB-T100	150
	200	MB-T200	310
	400	MB-T400	340
	600	MB-T600	360
	800	MB-T800	520

* Wall mounted units

TRANSIENT VOLTAGE SUPPRESSION

This option utilizes an encapsulated bi-directional, parallel transient suppression network circuit to provide protection from the damaging effects of transient voltage activity in the normal mode (L-N,L-L) and common mode (N-G,L-G). The transient voltage suppressors are UL1449 listed and exceed category C3 system exposure levels per ANSI/IEEE C62.41, 1991. All Staco Power Conditioners include this option as standard.

Not available on rack mount units.

Other Options Available

- Primary Circuit Breaker
- Secondary Circuit Breaker
- Special Input/Output metering
- Custom Designs
- Test Sets

GENERAL SPECIFICATIONS

AC INPUT CHARACTERISTICS

Voltage: Refer to Selection Charts

Phase: Refer to Selection Charts

Frequency: Refer to Selection Charts

Voltage Range: +10% to -20%, typical

SYSTEM CHARACTERISTICS

Efficiency:

Voltage Regulators: 99% typical, at full load

Power Conditioners: 97% typical, at full load

Heat Dissipation:

Voltage Regulators: 38 BTU/Hr/kVA, typical

Power Conditioners: 95 BTU/Hr/kVA, typical

Impedance:

Voltage Regulators: Less than 1%

Power Conditioners: Less than 3%

Noise Attenuation:

Voltage Regulators: 38 dB Common Mode
(with TVSS option) 36 dB Transverse Mode

Power Conditioners: 120 dB Common Mode
60 dB Transverse Mode

AC OUTPUT CHARACTERISTICS

Voltage: 120 to 600 VAC

Load kVA: 2.5 to 500 kVA

Load Current: 10 to 1388 Amps

Load Capacity:

33% Overload, 2 hours

50% Overload, 1 hour

100% Overload, 15 minutes

1000% Overload, 30 cycles

Load Power Factor: 0 lagging to 0 leading

Regulation: $\pm 1\%$ or better

Response: Less than 2 cycles

Correction Rate: Refer to Selection Charts

Harmonic Distortion: None added



ENVIRONMENTAL

Ambient Operating:

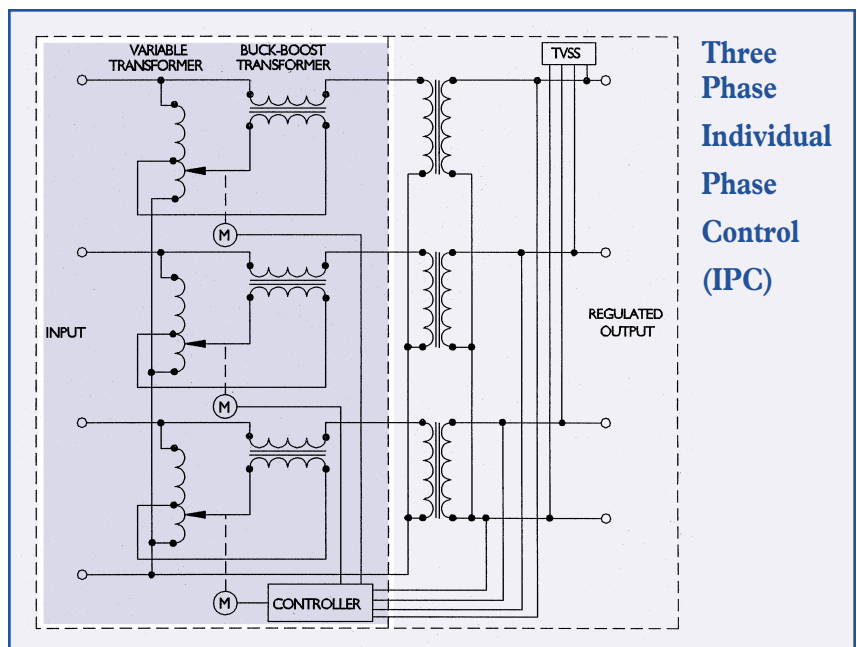
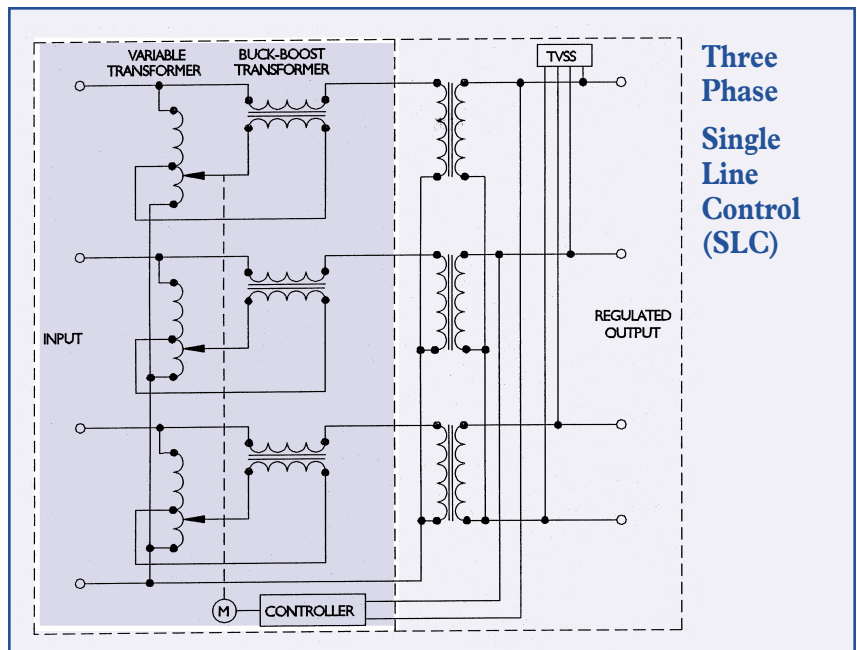
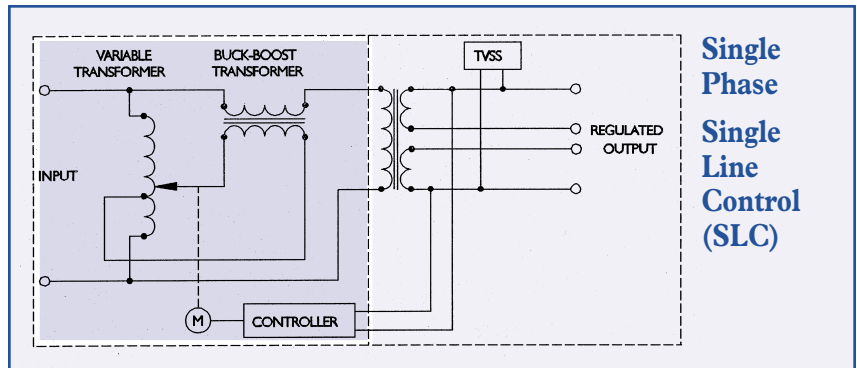
Temperature: 0°C to 50°C

Relative Humidity: 0 to 95%, non-condensing

Operating Altitude: 10,000 feet

Voltage Regulator section only 
Power Conditioner 

CIRCUIT DIAGRAMS



SELECTING STACO VOLTAGE REGULATORS and POWER CONDITIONERS

Selecting the Staco Voltage Regulator or Power Conditioner best suited to your specific requirements is easy once you make the following determinations:

VOLTAGE REGULATOR OR POWER CONDITIONER

The first step in the product selection process is to determine what type of product is required. A voltage regulator is designed to take the system input voltage and provide a regulated output voltage. The main difference between a regulator and a power conditioner is that a power conditioner also contains a transient voltage suppression package plus an output isolation transformer. A power conditioner provides output regulation plus load isolation and electrical noise attenuation. If system brownouts are the major concern, select a Voltage Regulator. If electrical noise, as well as brownouts, are the major application concern or if load isolation or system voltage step-down is required, choose a Power Conditioner. Voltage Regulator selection tables start on page 12 and the Power Conditioner selection tables start on page 16.

SINGLE OR THREE PHASE

The second step is to determine the type of load to be supplied. If the load is a single phase load, choose a single phase Regulator or Power Conditioner. If the load is three phase or is a combination of single and three phase loads, select a three phase unit. Product selection tables start with single phase units followed by three phase units.

VOLTAGE

The third step is to determine the selected unit's voltage rating. There are only a few different nominal system voltages used throughout the world. The basic product selection tables, starting on page 12, have been designed to meet 95% of the day-to-day needs. Staco Voltage Regulators, unlike some of the other regulator technologies, are designed with an adjustable output voltage setpoint. The charts below show standard output voltage setpoints available with the standard regulators listed in the selection tables. Using this output setpoint feature, 11 basic regulator voltage families can provide a $\pm 1\%$, or better, output regulation for 36 different world system voltages.

SINGLE PHASE • VOLTAGE REGULATORS

System	Output Voltage Setpoint	Base Unit Voltage	Input Voltage Range	Hz
(2 wire)	100	120 60 Hz *	80 - 110	50/60
	110		88 - 121	60
	115		92 - 26	60
	120		96 - 132	60
	200	240 60 Hz *	160 - 220	50/60
	208		166 - 229	60
	220		176 - 242	60
	230		184 - 253	60
	240	380 50/60 Hz	192 - 264	60
	347		278 - 381	50/60
	380		304 - 418	50/60
	400		320 - 440	50/60
	415	480 60 Hz	365 - 456	50/60
	440		352 - 484	60
	460		368 - 506	60
	480		384 - 528	60
	575	600 60 Hz	460 - 632	60
	600		480 - 660	60

THREE PHASE • VOLTAGE REGULATORS

System	Output Voltage Setpoint	Base Unit Voltage	Input Voltage Range	Hz
Delta (3 wire)	200	240 60 Hz	160 - 220	50/60
	220		176 - 242	60
	230		184 - 253	60
	240		192 - 264	60
	400	480 60 Hz	320 - 440	50/60
	415		365 - 456	50/60
	440		352 - 484	60
	480		384 - 528	60
Wye (4 wire)	200	208 60 Hz	160 - 220	60
	208		166 - 229	60
	220		176 - 242	60
	380	380 50/60 Hz	304 - 418	50/60
	400		320 - 440	50/60
	415	480 60 Hz	365 - 456	50/60
	440		352 - 484	60
	480		384 - 528	60
	575	600 60 Hz	460 - 632	60
	600		480 - 660	60

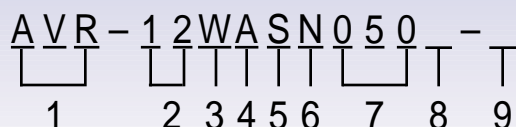
* Type SVR regulators are 50/60 Hz rated for all setpoint voltages.

Three phase system voltages are either Delta or Wye depending on whether a system neutral is available. A Delta system has only three conductors or wires. A Wye system has three conductors plus a system neutral. A Delta system is known as a three phase, three wire system, where the Wye system is known as a three phase, four wire system where the fourth wire is the system neutral. The type of three phase supply system must be determined for proper Voltage Regulator or Power Conditioner application. Staco offers both Delta and Wye three phase units as standard catalog items. Special voltage units are available, contact the factory for product information. Domestic units are 60 Hz rated and international units are 50/60 Hz rated.

SIZE

The fourth step in the selection process is to determine the unit's kVA rating. The product selection tables list both the unit's kVA rating and maximum output amperes. Knowing either the load kVA or amperes, select a unit that meets or exceeds the load requirements. The kVA ratings listed in the selection tables are based on a unit's maximum output ampere rating at its listed output voltage. If a Voltage Regulator is being selected based on the output set-point feature, the regulator should be selected based on the maximum output amperes which remain constant over the unit's output voltage setpoint range. The output kVA will then need to be recalculated based on the output voltage setpoint and the unit's maximum output amperes.

As a final step review the application to determine if any options are required.



STACO CATALOG NUMBERING SYSTEM

To assist in the understanding of the Staco catalog numbering system, a brief explanation follows below:

1: Product Type

AVR -- Voltage Regulator, analog control
 MVR -- Voltage Regulator, micro-processor control
 PLC -- Power Conditioner, analog control
 MLC -- Power Conditioner, micro-processor control
 SVR -- Stepper Voltage Regulator
 SLC -- Stepper Power Conditioner

2: Voltage

12 -- 12 to 120 volts
 20 -- 208 to 208 volts
 21 -- 240 to 120/240 volts
 22 -- 240 to 208Y/120 volts
 24 -- 240 to 240 volts
 27 -- 277 to 277 volts
 38 -- 380 to 380 volts
 41 -- 480 to 120/240 volts
 42 -- 480 to 208Y/120 volts
 48 -- 480 to 480 volts
 60 -- 600 to 600 volts
 61 -- 600 to 120/240 volts
 62 -- 600 to 208Y/120 volts

3: Input Range/Regulation

G -- +20% to -20%/ ±1%
 H -- + 6% to -10%/ ±1%
 N -- + 7% to -11%/ ±1%
 P -- + 7% to -17%/ ±1%
 Q -- + 10% to -10%/ ±1volt
 T -- + 10% to -15%/ ±1volt
 W -- + 10% to -20%/ ±1%
 X -- + 25% to - 30%/ ±1%
 Z -- + 15% to -15%/ ±1%
 V -- + 15% to -30%/ ±1%

4: Phase/Hertz

A -- Single Phase, 60 Hertz
 B -- Single Phase, 50/60 Hertz
 C -- Three Phase, 60 Hertz
 D -- Three Phase, 50/60 Hertz

5: Control

I -- Individual Phase Control
 S -- Single Line Control

6: System

D -- Delta input, Delta Output
 X -- Delta input, Wye Output
 Y -- Wye input, Wye output
 N -- Not used

7: KVA Rating

Actual unit kVA, max of four positions

8: Rack Mounted Unit

R -- only used when unit is rack mount type

9: Options

D -- Digital Meter
 MA -- Analog Amp Meter
 MAD -- Digital Amp Meter
 O -- Output Contactor
 P -- Primary Circuit Breaker
 S -- Secondary Circuit Breaker
 T -- Transient Suppression