

Smart Grid solution

# Smarter voltage regulation

Integrated intelligence made simple  
by the voltage regulator experts

**Cooper  
Power Systems**  
by **EAT•N**

# POWER GRID

## Challenges

Building Smart Grid infrastructure begins with advanced apparatus and integrated communications



Eaton's Cooper Power Systems integrates:

- 1 Proven reliability
- 2 Continuous innovation
- 3 User-friendly interface
- 4 Exceptional distribution system performance

### Service to the power consumer

Voltage management is critical to users of electrical equipment and sensitive electronics. Commercial, industrial, and residential applications require a consistent voltage despite load current variations caused by expanding system demand and load profile fluctuations.

### Financial considerations

While demands on the power grid expand, budgets remain tight. Often, the purchase of new equipment and the cost associated with installation and maintenance of the equipment must be justified by projected savings.

### Smart Grid complexity

Implementation of Smart Grid advancements and new technologies for power grid control and data acquisition require specialized expertise. Solutions are needed that are easy to implement and provide results without a lot of complication.



# VOLTAGE REGULATION Solutions

## Eaton's Cooper Power Systems voltage regulators

- Industry leader in voltage regulator technology and innovation
- Most advanced voltage regulator control in the industry
- Secure communications integration with grid-wide line of advanced controls
- More advanced solutions packaged to meet the needs of power suppliers
- Quickest responding single-phase step-voltage regulator tap changer in the industry
- Product support and expertise that is unmatched in the industry



The CL-7 regulator control is specifically designed to meet the need for Smart Grid-ready equipment with an array of communications options. These options easily integrate with Eaton's Cooper Power Systems Yukon™ enterprise software and other advanced controls to meet system control and data acquisition requirements.

Power saving Smart Grid advancements such as Integrated Volt/VAR Control (IVVC) and Conservation Voltage Reduction (CVR) are easily implemented with our industry leading voltage regulating apparatus, control and communication interfaces.

The speed of the patented Quik-Drive™ tap-changer along with the unique Voltage Limiter capabilities of the control enable the fastest response available for extreme voltage swings.

Because the Eaton's Cooper Power Systems voltage regulator apparatus and control are designed to operate together, exclusive features such as Duty Cycle Monitor (DCM), Preventative Maintenance Tapping (PMT™) and motor trouble diagnostics are available to alert users to a need for maintenance. Proactive maintenance and quick alerts to impending issues will minimize maintenance costs and system downtimes.

The Eaton's Cooper Power Systems CL-7 multi-phase control, another major advancement from the industry's leader in innovation, enables operation of up to three voltage regulators with a single control. New multi-phase control options include true three-phase metering and innovative gang-operation strategies.

Eaton's Cooper Power Systems offers CYME™ engineering analysis software to assist with, the proper coordination of, voltage regulators and capacitors on your distribution system. This will help to minimize losses, improve voltage profiles, and balance loads between feeders.

Optimize energy savings, power quality, and asset management while minimizing power interruptions. Eaton's Cooper Power Systems voltage regulators are part of a comprehensive power management portfolio, an integral element in your Smarter Grid operation, and backed by expert technical support.

# Widest range of voltage regulator product offerings:

Pole-mount, platform-mount, substation and underground pad-mount, and substation models

## Single-phase, 32-step voltage regulators

Our line of voltage regulators combines all of the advantages Eaton's Cooper Power Systems has to offer into a complete regulator package. Nowhere else can you get a single-phase regulator with the innovative CL-7 control and complementary tap-changer technology that is decades ahead of the competition. Combine these with more than a half-century of experience and expertise.

The multi-unit designs offer 2 or 3 single-phase regulators in one tank for space-saving flexibility. These regulators are compatible with underground power distribution systems, and offer a safe, tamper-resistant cabinet built to the same standards of security as our traditional pad-mounted transformers. With a lower profile footprint than traditional overhead installations, they can be discretely installed in sensitive residential and commercial areas.

## Substation voltage regulators (SVR)

Eaton's Cooper Power Systems leads the industry in the application of single-phase voltage regulators into substations regulating loads up to 60 MVA. With features such as fan cooling and insulating fluid filtration, SVRs provide a viable option superior to the use of On-Load Tap-Changers (OLTC) with the added flexibility of regulation separate from the power transformer. The CL-7 multi-phase control offers additional advanced features such as true three-phase metering and phase-voltage averaging ganged operation.

## Modular Integrated Transportable Substation (MITS)

Voltage regulator products can be combined with other power distribution equipment into a Modular Integrated Transportable Substation (MITS) for mobile, temporary, or emergency needs. These unique, cost-effective, turnkey installations are fully integrated and factory pre-engineered. An electrical power substation or any other grouping of electrical equipment is assembled on a self-supporting structural base, or mounted on a Department of Transportation (D.O.T.) compliant trailer. The mobile mounting is particularly suitable for temporary use during construction or disaster relief.

## Pad-mounted voltage regulators

Designed for use in public and commercial areas with underground distribution lines, pad-mounted regulators are available in single-phase, 2-in-1, and 3-in-1 configurations.

*Voltage ratings are available from 2.4 kV (60 kV BIL) to 34.5 kV (200 kV BIL) for 60 Hz and 50 Hz systems.*



Substation Class Regulators



Distribution Class Regulator



Modular Integrated Transportable Substations



Pad-mounted Regulator

## History of innovative design

1954

- Single-phase Step-Voltage Regulators introduced

1959

- Step-voltage regulator with direct drive tap-changer

1984

- Microprocessor-based control for voltage regulators

1988

- Microprocessor-based CL-4 voltage regulator control



Eaton's Cooper Power Systems is uniquely qualified with over 55 years of experience in voltage regulator design, application, training, and technical support. This experience is the reason we are the global leader in single-phase voltage regulators and controls, whether measured by market share or innovation. We continuously invest to improve power quality and delivery efficiency, reduce maintenance costs and extend the life of the regulator apparatus and control.

#### Designed with experience

Eaton's Cooper Power Systems regulator designs provide superior dielectric and short-circuit strength, higher efficiency, and extended life:

- Unique reactor design, consisting of a ground isolated shell type structure minimizes the effect of through-faults and ensures longer life under severe operating conditions. The dual-coil reactor design with interlaced windings minimizes voltage drop and no-load losses.
- Coil strength is improved through the use of hot pressed, thermally-upgraded, epoxy-coated insulating paper.

- Voltage regulator tanks have fully welded external components to eliminate water entrapment leading to premature corrosion.

Industry leading product development is proven by the most comprehensive and fully automated manufacturing test line in the industry. Routine production tests are conducted at full rated voltage up to 35 kV.

#### 1997

- Pad-mounted, single-phase voltage regulator—improves safety and environmental impact, and reduces costs

#### 1997

- Dual cable disconnects with electronic CT protector improve safety and flexibility

#### 1999

- QD8 Quik-Drive tap-changer provides longer life and enhanced power quality



**The CL-7 steps into the future with exclusive features such as:**

**Modularity**

Install only the features that you need such as integrated communication interface boards, expanded input/output points, expanded communications protocol support, and battery backup. Spare parts management is simplified; keep modular parts on the shelf for easy installation when needed.

**Multi-phase regulation option**

The CL-7 offers an industry exclusive multi-phase option which allows the operation of two or three regulators with the use of a single control. The multi-phase option offers benefits such as a single communications point, less hardware to program and maintain, true three-phase metering, and advance gang-operation modes.

**Communications interface**

The CL-7 offers eight different integrated interface options including: Serial RS-232, serial RS-485, Ethernet copper, three versions of Ethernet multi-mode fiber, Ethernet single-mode fiber, and multi-mode serial fiber. Support is available for communications protocols including DNP3, IEC 60870, MODBUS, 2179, IEC 61850, and SNTP.

**ProView™ NXG software**

A single software program interfaces with the CL-7 control and other Eaton's Cooper Power Systems control products including the CL-6 voltage regulator control, Form 4D recloser control, the SPEAR™ recloser control, CBC-8000 capacitor bank control, and the GridAdvisor™ Smart Sensor.

*The CL-7 is the next generation in the line of trusted CL controls by Eaton's Cooper Power Systems. The new control utilizes nearly all of the familiar features of the CL-6 line of controls; if you know how to use the CL-6, you know how to use the CL-7.*

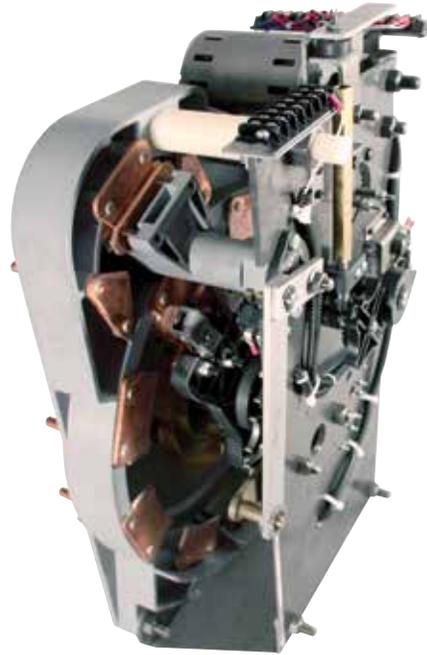
**History of innovative design**

- |   |  |  |  |
|---|--|--|--|
| <p><b>2003</b></p> <ul style="list-style-type: none"> <li>DNP Class data reduction provides efficient communications and ease of use</li> </ul> | <ul style="list-style-type: none"> <li>QD5 Quik-Drive tap-changer provides longer life and enhanced power quality</li> </ul> | <p><b>2004</b></p> <ul style="list-style-type: none"> <li>Poly position indicator is corrosion free for extended life</li> </ul> | <ul style="list-style-type: none"> <li>CL-6 control with programmable I/O increases programming flexibility, ease of use, and longer life</li> </ul> |
|---|--|--|--|

# QUIK-DRIVE

## tap-changer

Eaton's Cooper Power Systems leads the industry with advancements to the SVR tap-changer mechanism. The Quik-Drive tap-changer rotates through all 33 positions in less than 10 seconds – providing the quickest response for superior voltage regulation. Other manufacturer's regulators still use 80+ year-old spring-driven technology requiring 5 seconds per step.



### The Quik-Drive offers:

#### Speed:

- Quickest response to large voltage excursions
- Taps eight steps (5%) in just over two seconds

#### Accuracy:

- The tap-changer Geneva Gear drive ensures accurate steps without calibrated springs
- Electrical feedback circuit ensures accurate tap position tracking and operations count by the control

#### Simplicity:

- No springs reduces maintenance and provides faster response
- Fewer moving parts by 20% means greater durability and easier maintenance

### Tap-changer integration with the CL-7 control

Since Eaton's Cooper Power Systems developed the control, the tap-changer, and the rest of the voltage regulator apparatus, full integration of all components is realized. Advantages of this integration include:

- Duty Cycle Monitor (DCM)
  - Predictive maintenance feature eliminates unnecessary maintenance – reducing downtime and lowering costs. Valuable operational maintenance information, used in conjunction with control configurable logic and SCADA communications, can alert your control center to impending maintenance requirements. DCM calculates the life

used for each arcing contact on the tap-changer. The control uses advanced algorithms, proprietary design information and measured power conditions during tap changes to estimate contact erosion.

- Preventive Maintenance Tapping (PMT™) and Motor Trouble diagnostics
  - PMT performs user-scheduled automatic operations to prevent contact coking and provide periodic operations checks. Coking can occur in heavily loaded, under-oil contacts and can be seen in the reversing switch when a regulator rarely taps through neutral. Set the control to initiate operations using criteria such as time of day, maximum steps

from neutral, or when the regulator is lightly loading. PMT can be used in conjunction with the Motor Trouble diagnostics and SCADA communications to send an alert regarding operational issues. This can eliminate the need for regular function checks and reduce downtime.

- Duty Cycle Monitor (DCM) and Preventative Maintenance Tapping (PMT) improves equipment reliability

#### 2005

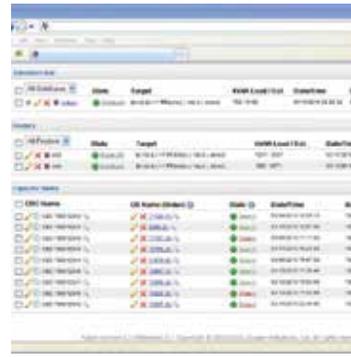
- 3-in-1 pad-mounted design improves application flexibility and safety, and reduces footprint and costs

#### 2007

- QD5 Quik-Drive tap-changer polymer insulating board improves contact alignment, providing the quickest voltage regulation response

#### 2008

- Junction box redesign improves quality and ease of maintenance



# SMARTER GRID SOLUTIONS:

## IVVC improves power quality and system efficiency

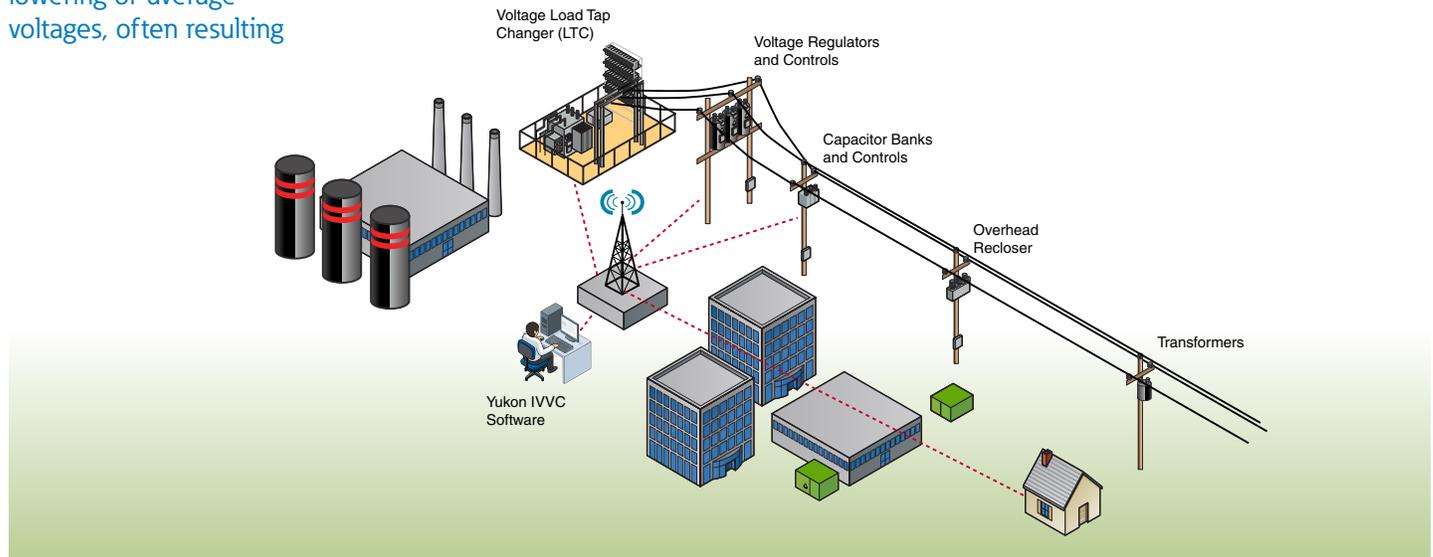
Integrated Volt/VAR Control (IVVC) software communicates, analyzes, and controls all voltage regulators, capacitors, and OLTCs on a system to maintain voltage within acceptable levels as load increases or decreases. This allows leveling of each feeder's voltage profile and lowering of average voltages, often resulting

in significant energy savings. IVVC software uses all of the built-in capabilities of the Eaton's Cooper Power Systems voltage regulator package: the regulator with the CL-7 control, and innovative tap changer.

### Distribution automation solution

Eaton's Cooper Power Systems offers a full suite of power quality software and apparatus to support your Volt/VAR management solution. With unparalleled expertise to make your automation seamless, we offer:

- Single and multi-phase voltage regulators
- CL-7 voltage regulator controls
- Capacitor banks
- CBC-8000 capacitor bank control
- Yukon™ Volt/VAR management automation software
- CYME™ power engineering software



### History of innovative design

- CL-6 control redesign delivers a smaller, more flexible package to fit inside the voltage regulator control box of any manufacturer.

#### 2009

- CL-6 firmware upgrades support Leader/Follower schemes and Auto-Restore Local

- Ethernet interface

#### 2010

- CL-6 firmware upgrades introduce Alternate Settings and Adaptive Add-Amp



# Key to your Smart Grid is smart apparatus

## Optimal feeder voltage

Yukon IVVC software synchronizes with capacitors and voltage regulators leveling and lowering the feeder voltage profile. The voltage regulator works in conjunction with the capacitor delivering the optimal feeder voltage profile. Graph 1 below represents the Yukon IVVC software altering the voltage profile – resulting in a reduction of the average feeder voltage from 122 to 118 volts.

Power factor correction is a crucial element in improving energy efficiency and reducing losses. Graph 2 below represents before and after effective implementation of Yukon Volt/VAR management software.

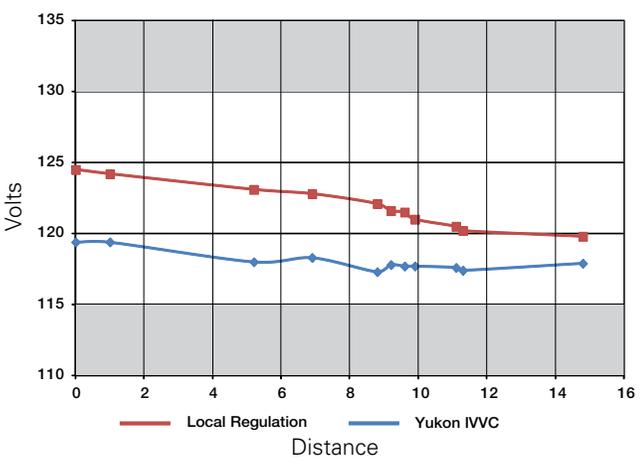
## Power system studies for optimized results

Maximize the benefits from implementing a Volt/VAR management solution using Eaton's Cooper Power Systems CYME engineering team. Power system studies are offered to identify the best combination of voltage regulation equipment to optimize feeder voltage profiles and substation VAR management.

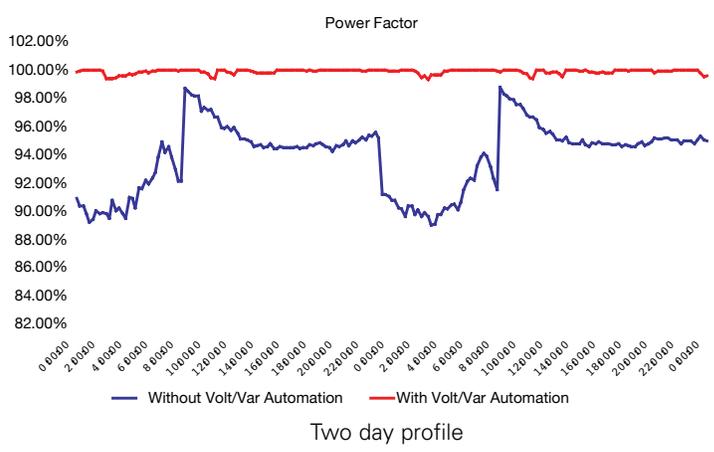
## Energy Efficiency

Eaton's Cooper Power Systems voltage regulators improve the efficiency of the system reducing costs:

- As a critical component of CVR and IVVC solutions
- When feeder automation alternates loading and power flow direction.



Graph 1. Voltage Profile: Local Regulation vs. Yukon IVVC



Graph 2. Yukon IVVC management software

### 2011

- Pioneers in development of Volt/VAR management system

- CL-6 adjusts automatically to load changes to increasing capacity and automating CVR or IVVC maintaining superior power quality and extending product life

### 2013

- Single and multi-phase voltage CL-7 regulator control launched

# DESIGN

# BUILD

# INTEGRATE

# SUPPORT

## Technical expertise before and after purchase

Eaton's Cooper Power Systems has the technical expertise to provide products best suited for a wide range of applications. Rely on our experienced Engineered-To-Order staff to create a voltage regulator design meeting your specifications and expectations. After the sale, technical support is available by phone and email, and in the field by Eaton's Electrical Services and Systems team and Field Application Engineers. Authorized Service Centers are located around the globe.

Our factory and traveling voltage regulator, control, IVVC, and capacitor workshops qualify for Continuing Education Units (CEUs). For more than 35 years, Eaton's Cooper Power Systems Voltage Regulator schools have trained more linemen, technicians, and engineers on the proper installation, operation, and programming of voltage regulators and controls than any other manufacturer in the industry.

## CASE STUDY 1.

### Utility IVVC software application

Utilities typically create operational plans for delivery of power within an acceptable voltage range at a planned power factor. One large utility evaluated Eaton's Cooper Power Systems technology to take a big-picture view of voltage regulators and capacitors to better optimize voltage levels and VARs. The business case for conservation voltage reduction (CVR) is complex. Factors include projected cost of fuel, emissions mitigation, and added generation capacity with a goal of reduced expenditures and lower utility bills for customers.

This large utility built the business case for technology investment through the use of Eaton's Cooper Power Systems CymDIST™ distribution planning power flow software.

After justifying the business case, they deployed voltage regulators, capacitor banks, and Yukon Volt/VAR management software - including Integrated Volt/VAR Control - supporting peak load reduction through voltage and 24/7 load reduction. An additional benefit included remote identification of capacitor bank problems. The result was achievement of the financial and operational benefits identified in the CymDIST planning studies.

*Utilities save on the cost of fuel and emissions mitigation, as well as a reduced need for additional peak capacity. Customers see smaller utility bills.*

## CASE STUDY 2.

### Commercial and industrial application

Industrial expansion in a small Mexican city had placed a heavy load on the city's aging power grid which had not kept pace with growing energy demands. A cardboard manufacturer in the city faced morning start-up with 10% voltage drops; it also was not uncommon to have intermittent voltage surges of 12-15%. The extreme voltage swings were causing damage to high-efficiency motors, electronics, drives, and programmable logic controls common in paper processing.

During a site visit to discuss the voltage problems, the Eaton's Cooper Power Systems technical representative also recognized the limited space availability and that the substation was located inside the plant - an electrical equipment room with limited access. The ideal solution for

this type of installation was Eaton's Cooper Power Systems unique pad-mounted regulators with their complete dead-front construction, tamper-resistant cabinet, and low profile. The electrical ratings of the three regulators in this installation were:

- 150 A
- 7.62 kV
- 114 kVA
- 60 Hz

*With Eaton's Cooper Power Systems voltage regulators and controls in operation, used in conjunction with capacitors, power factor improved from 0.94 to 0.98.*



### CASE STUDY 3.

#### Military application

Eaton's Cooper Power Systems supplied three pad-mounted voltage regulators and a power transformer without an on-load tap-changer (OLTC) to replace the aging OLTC equipment in a substation on a military base. Pad-mounted voltage regulators with tamper-resistant cabinets and underground system compatibility ideally suited the application in which space inside the substation enclosure was at a premium and installation of additional fencing would be costly.

After installation, the customer requested the addition of 3-phase ganged operation of the single-phase voltage regulators. The additional functionality was field installed with communications boards and fiber-optic cables added to enable the Leader/Follower control scheme. The inexpensive, easy to install solution not only met a customer need, but also illustrates the flexibility of the Eaton's Cooper Power Systems CL-series voltage regulator controls.

### CASE STUDY 4.

#### Modular Integrated Transportable Substation (MITS)

When Hurricane Sandy hit Rockaway Beach, NY, the storm surge left the 53rd Street substation under 5½ feet of water, according to the local utility spokesman. The substation was an air-insulated metal-clad design, which was particularly vulnerable to the salt water of the storm surge.

A nearby contractor had recently purchased an Eaton's Cooper Power Systems Modular Integrated Transportable Substation (MITS) to replace an aging substation for upstate New York. In the aftermath of the storm and with restoration of power a priority, he realized the MITS was the ideal solution to the problem at Rockaway Beach. The MITS is well suited for this type of application.

#### The MITS is:

- Prewired, tested, and ready to install upon leaving the factory. This saves significant installation time during the critical early hours of the disaster recovery effort.
- Compact in design. All substation components fit neatly onto a single skid making transportation manageable, even in a disaster area.
- Designed using shield-grounded cable which, are much less susceptible to storm surges.

This particular MITS was designed with:

- A bank of three single-phase pad-mounted voltage regulators to provide superior power quality.
- A 5 MVA power transformer to convert voltage from 34.5 kV to 13.2 kV.

- A pad-mounted recloser for feeder protection.
- A small single-phase power transformer supplying 120 V power to the control systems integrated into the unit.
- Extra features such as built-in spill containment, telescoping flood lights, and in-cabinet door lights, which are helpful for crews restoring power at night.

Once the MITS arrived on site, the line crew, engineers, and operation personnel immediately made the final connections between the damaged system and the MITS and restored power.

*The MITS was the ideal solution to restore power quickly at Rockaway Beach.*

**Voltage Regulator Technical Support:**

P: 866.975.7347 (US only)

P: 262.896.2591 (outside US)

E: RES-VRSupport@Eaton.com

Contact Hours:

Standard hours 7:00 am to 5:00 pm CST

**Eaton**

1000 Eaton Boulevard  
Cleveland, OH 44122  
United States  
Eaton.com

**Eaton's Cooper Power  
Systems Business**

2300 Badger Drive  
Waukesha, WI 53188  
cooperpower.com

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*Powering Business Worldwide*