THE CRITICAL ROLE OF SCR POWER CONTROLLERS IN THERMAL PROCESSING

The Kendall Group Technology Summit – August 1, 2017

DEMYSTIFYING THE TEMPERATURE CONTROL LOOP:
THE CRITICAL ROLE OF SCR POWER CONTROLLERS IN THERMAL PROCESSING

How to Control Temperature-Critical Processes

Measurement: Optical Temperature Pyrometer Capabilities

Power Control: SCR Power Controller Capabilities

Integrated Solution and Critical Features

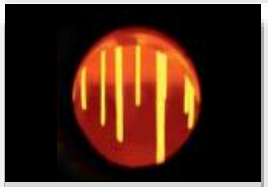
FULLY INTEGRATED TEMPERATURE-CONTROL SOLUTION

SCR power controllers and pyrometers integrated into a single solution

- Closed-loop solution for real-time control of temperature-critical processes
- Increased product uniformity, repeatability, and throughput

MARKETS AND APPLICATIONS: FROM MELTING TO DRYING

Electric Power Controller Markets and Applications



Semiconductor & Solar

- STC converter
- Crystal pulling
- Ingot furnaces
- Vapor deposition
- Diffusion
- LED

Oil, Gas, & Chemical

- Pipe heating
- Bath heating
- Coating processes
- Extrusion

Industrial Furnace & Metals

- Heat treating
- Vacuum furnace
- Hardening
- Tension release
- Melting
- Sintering

Glass & Crystal

- Float
- Boosting
- Bending
- TFT
- Fiberglass
- Sapphire

Other

- Rebuilds & maintenance
- DC rectifiers
- AC supplies
- Spare parts
- Special applications

Melting | Heating | Forming | Bending | Drying

TEMPERATURE MEASUREMENT

What is a Pyrometer and
How Does it Work?

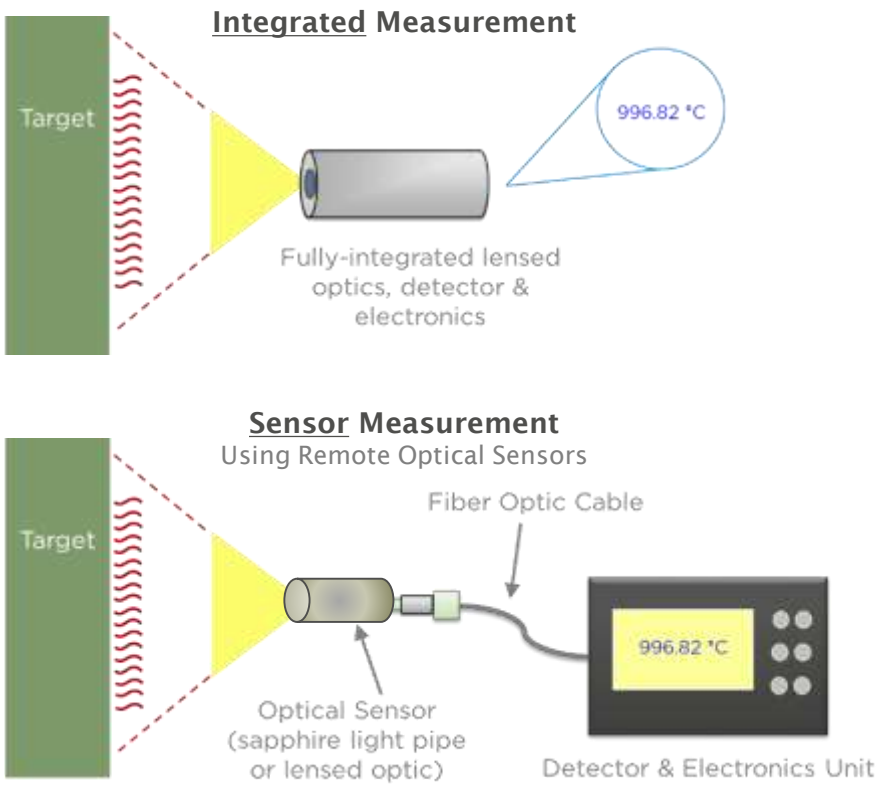
WHAT IS A PYROMETER?

Non-contact, Optical Temperature Measurement

- Measures infrared thermal radiation energy from an object (in photo current) and converts this measurement into temperature
- Uses a wavelength-specific filter (most pyrometers)
  - Blocks all unwanted “stray” energy
  - Measures only at a specific wavelength
  - Requires pre-selected wavelength based on materials
- Calculates temperature based on the amplitude of the collected thermal radiation
- Provides excellent accuracy and repeatability for critical thermal processes

TWO DIFFERENT PYROMETER TYPES

Constant, Precise Control of Thermal Processes

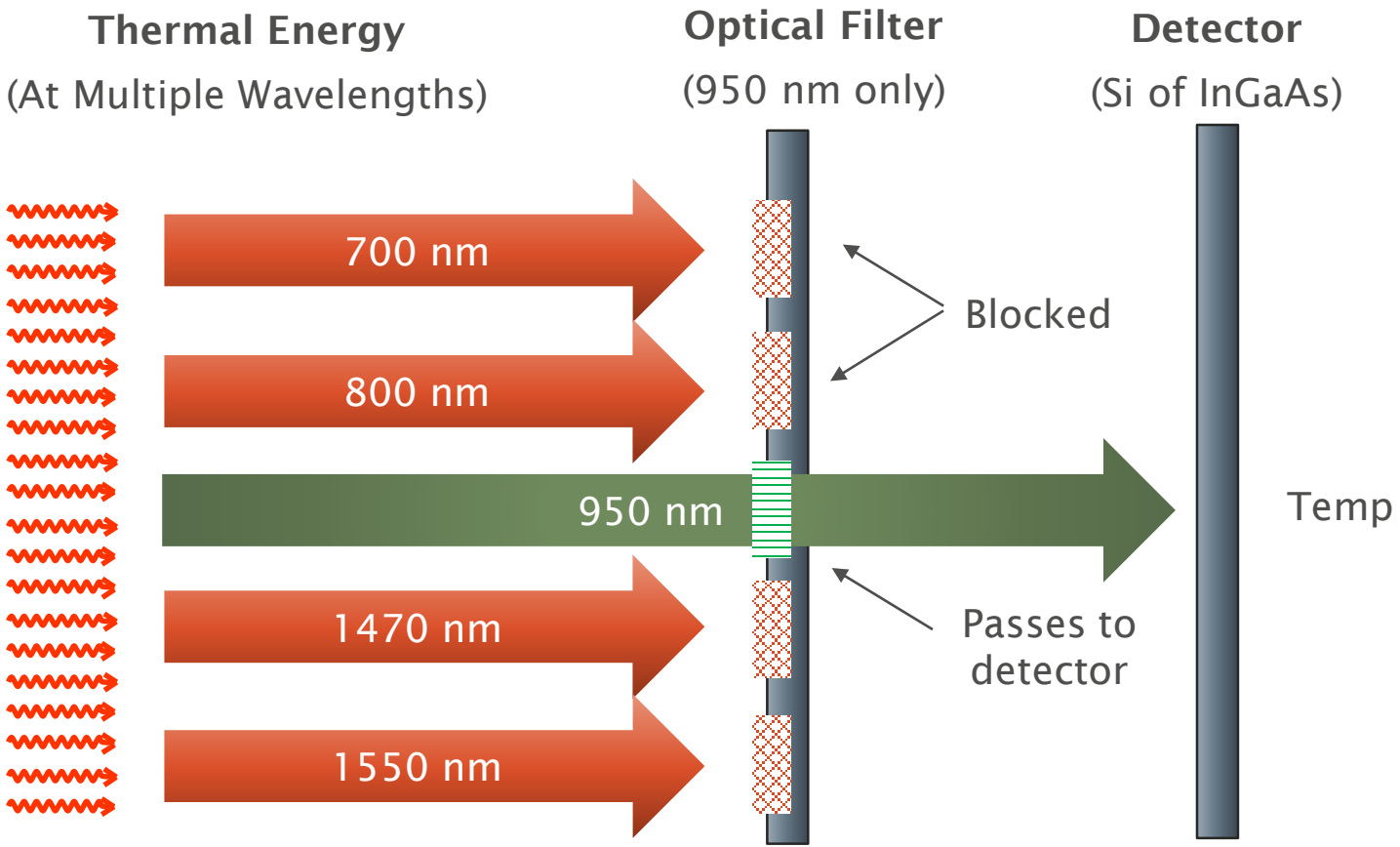


- Ideal for moving, rotating, or inaccessible work pieces, or when direct physical contact would damage the work product
- Wide temperature measurement range, from 300°C (572°F) up to 2200°C (3992°F), based on selected wavelength
- Non-contact device, can provide years of service, typically requiring minimal maintenance or re-calibration, and may be re-calibrated where required by process standards for measuring instrumentation

FUNDAMENTALS FOR A GOOD MEASUREMENT

- Selecting the correct wavelength
  - Based on material properties
    - Typically, select “shortest” (lowest) wavelengths possible
  - Determines (min to max) temperature ranges
  - Minimizes specular (shiny) vs. diffuse (absorbing) effects
- Managing “stray light/energy” in the measurement environment
  - Heaters, exposed surfaces
  - Employ physical blocking of “hot” sources
  - Advanced pyrometers offer background subtraction
- Managing emissivity effects
  - Choice of a two-color (dual wavelength) pyrometer
  - Advanced pyrometer with active emissivity compensation

BLOCKING OPTICAL FILTER – INSIDE PYROMETER



MEASUREMENT BY WAVELENGTH

- Wavelength
  - Choose based on substrate's material properties
  - Determines temperature min to max range

UV	Near-IR Pyrometers	Mid-IR Pyrometers
300 nm	700 nm to 1500 nm	2.3 µm to 5.2 µm

UV Energy
- Lamps
- Curing
- Irradiation

Core Industrial Materials
- Steels
- Non-ferrous metals
- Graphites
- SiC materials
- Ceramics
- Heater surfaces

Glass
Temperature Measurement (5.2 µm)

Plastics
(8 to 14 µM)
→

WHAT IS EMISSIVITY AND WHY DOES IT MATTER?

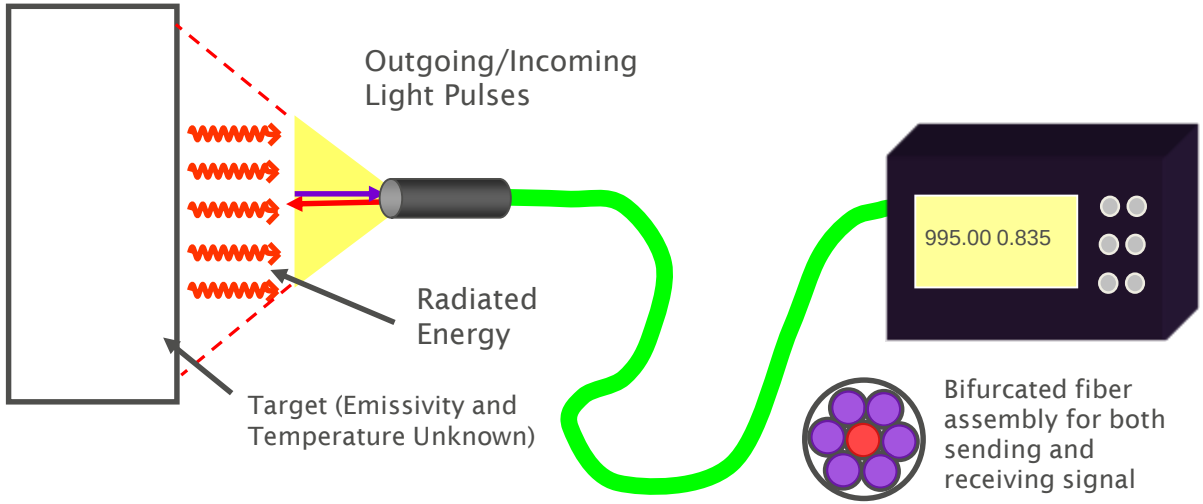
- Emissivity (ε) is a physical property of the material being measured
- It is based on the work product's reflectance
- Emissivity is expressed as a correction factor (0 to 1) that helps scale/correct the measured temperature
- All single-wavelength pyrometers have an input for emissivity (ε) to help ensure accurate measurement
- Two requirements for accurate temperature measurement:
  - Emissivity is known at the start of the measurement
  - Emissivity does not change during processing

WHAT IF EMISSIVITY IS UNKNOWN OR CHANGES?

- Any changes can lead to errors in measurement.
- Size/scale of the errors are based on wavelength and temperature.
- These errors can occur throughput the entire measurement.
  - Oxidation during processing
  - Deposition of specific coatings
  - Changes that occur to the work product's surface
- Two ways to minimize/manage emissivity changes:
  - Use two-color ratio pyrometer.
    - Caveat: Any surface changes must affect both wavelengths the same, or large errors can result.
  - Use pyrometer with integrated emissivity measurement.

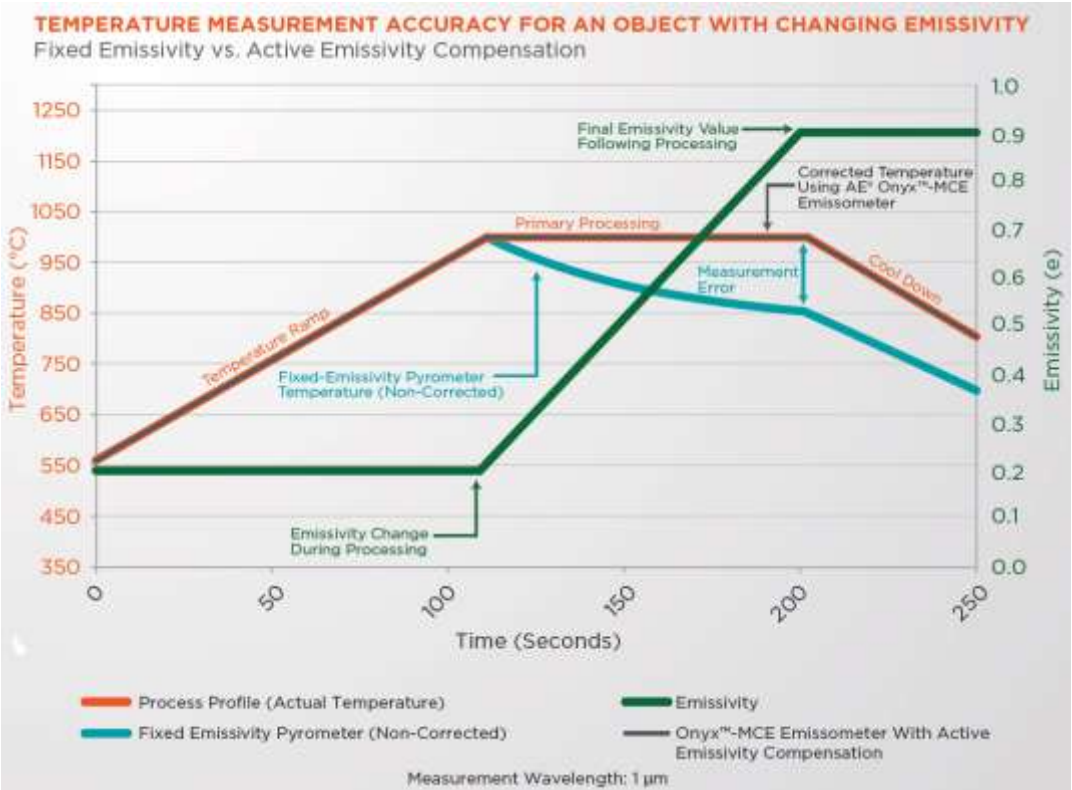
EMISSOMETER OPERATION

- Emissometer illuminates target with series of light pulses.
- Reflectivity is measured. Emissivity is calculated real time: e=1-R
  - Valid for opaque, specular targets only
- Emissivity is measured at same wavelength as pyrometer.
- Pyrometer function is compensated for the target emissivity.



MEASUREMENT OF AN OBJECT WITH CHANGING EMISSIVITY

Measurement Wavelength: 1 µm



INDUSTRIAL PYROMETERS

Key Features

Onyx™-S
Onyx™-S2C Two Color

Onyx™-MC
Onyx™-MCE Active Emissivity

Single-Channel Pyrometer

- Single and two-color ratio dual-wavelength measurements
- Wide temperature ranges
- Industrial fieldbus communications (Ethernet IP)
- Integrated laser alignment
- IP65 compliance (against dust, water)
- Higher ambient temperatures (70°C)
- Rockwell AOP (Add on Profile) - available Q3 2017

Multi-Channel Pyrometer

- 1 to 4 measurement channels
- Temp-only or active-emissivity configurations
- Optional industrial enclosures (IP60)

TEMPERATURE CONTROL

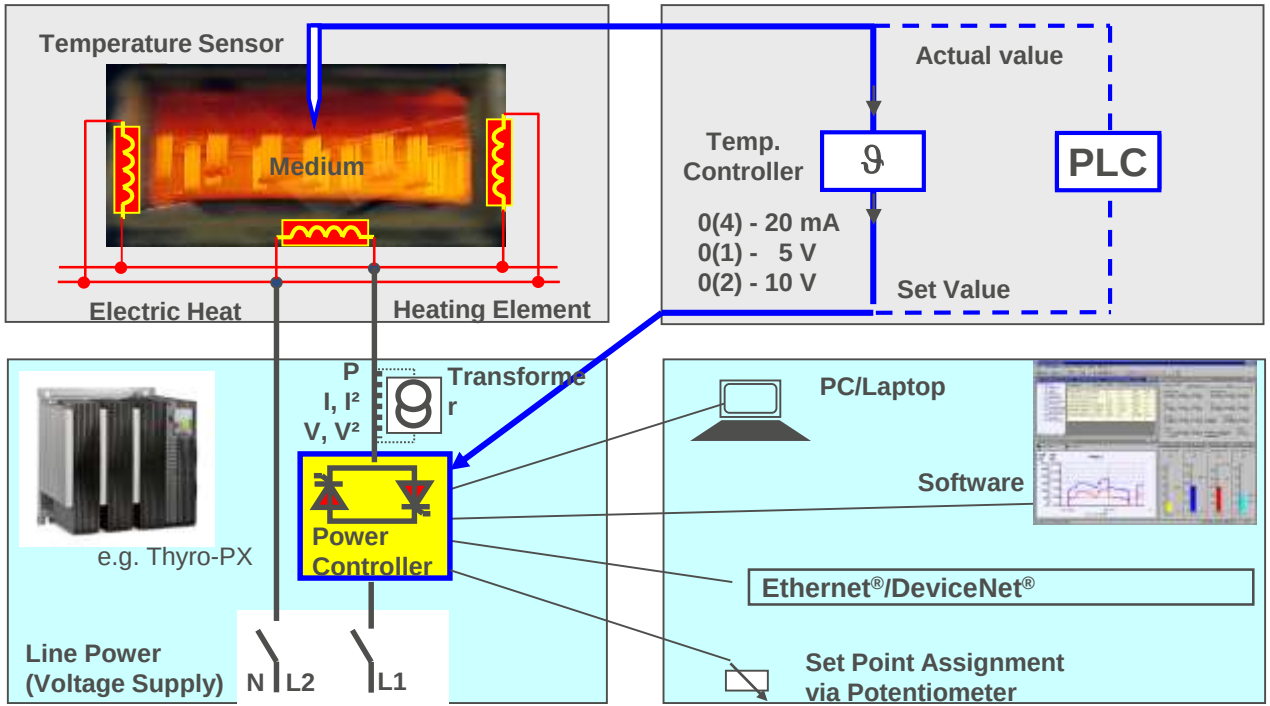
What is an SCR Power Controller
and How Does it Work?

WHAT IS AN SCR POWER CONTROLLER?

- Can be used in all applications requiring heating, melting, or bending
- Controls electrical power, current, or voltage with high precision and reproducibility
- Ensures high manufacturing quality and cost efficiency through:
  - Energy efficiency
  - High accuracy
  - Flexibility
  - Small footprint

WHAT IS AN SCR POWER CONTROLLER?

Power and Temperature Control Loops



WHY SHOULD I USE AN SCR POWER CONTROLLER?

SCR Power Controllers

- Provide precision power control in temperature-critical electric heating manufacturing processes
- Ensure high quality and cost efficiency through their high accuracy, flexibility, small footprint, and energy efficiency

Typical Applications:

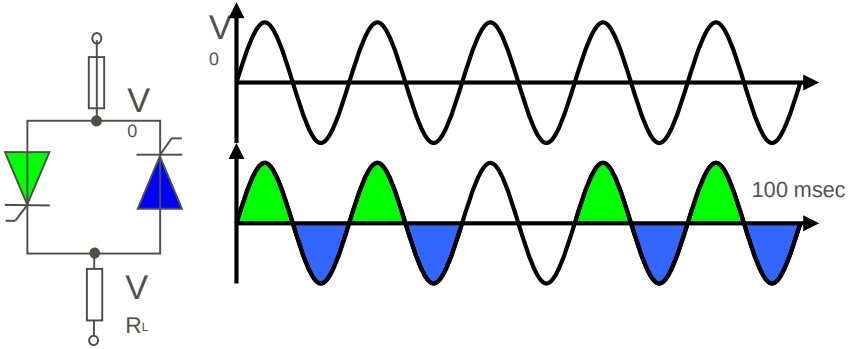
- High-temperature electric elements
- Transformer-coupled heating loads
- Highly automated manufacturing processes

ENERGY EFFICIENCY

- At 99.5% efficiency, SCR power controllers offer a distinct advantage over alternative devices such as IGBT-based power supplies and converters.
- Modern SCR power controllers offer multiple operation modes, enabling users to select the best control method for their application.

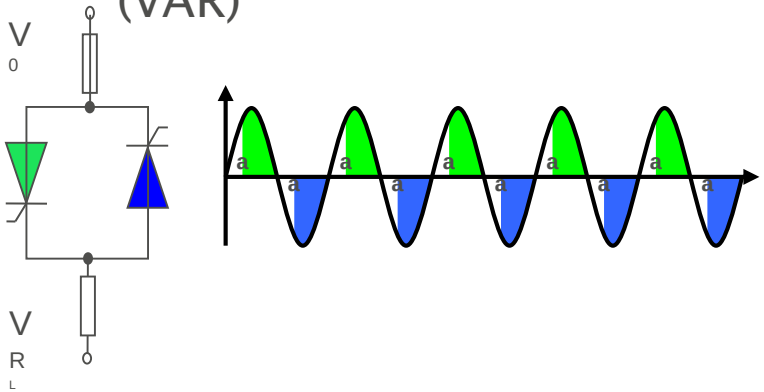
BASIC OPERATION MODES

- Full-Cycle Firing (Zero Cross, TAKT)



- For loads with thermal inertia
- Benefits:
  - Minimum control reactive power
  - Almost no harmonics
  - Easy to synchronize
- Drawback:
  - Flicker voltage range
  - High inrush current for transformer loads

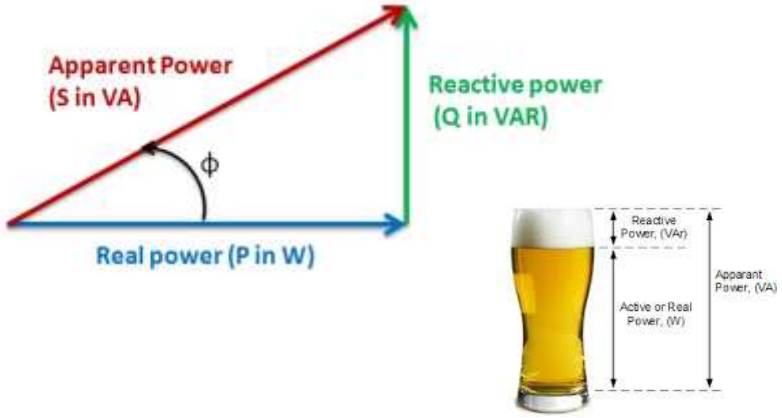
- Phase-Angle Firing (VAR)



- For high dynamic loads with small thermal inertia
  - High control dynamic
  - Soft and bumpless loading
  - Exact current-limit setting
- Harmonics

WHAT DOES *POWER FACTOR* MEAN?

- Power factor is the ratio between the kW and the kVA drawn by an electrical load where the kW is the actual load power and the kVA is the apparent load power.
- Simply, it is a measure of how efficiently the load current is being converted into useful work output, and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system.



Apparent Power:

$S = P^2 + Q^2$

Real Power:

$P = S \times \cos\varphi$

Reactive Power:

$Q = S \times \sin\varphi$

Power Factor cos φ:

$\cos \varphi = P/S$

OPERATION MODE AND POWER FACTOR

- Phase-angle operation can result in power factors of less than 1
  - Power factors less than 1 can result in generation of harmonics and potential RFI

- The availability of multiple operation modes, such as zero-cross and full-cycle firing (TAKT), allows you to select the best option for your application to improve power factor.

- Ideal power factor = 1

ADVANCED ENERGY AND THE CONNECTED ENTERPRISE

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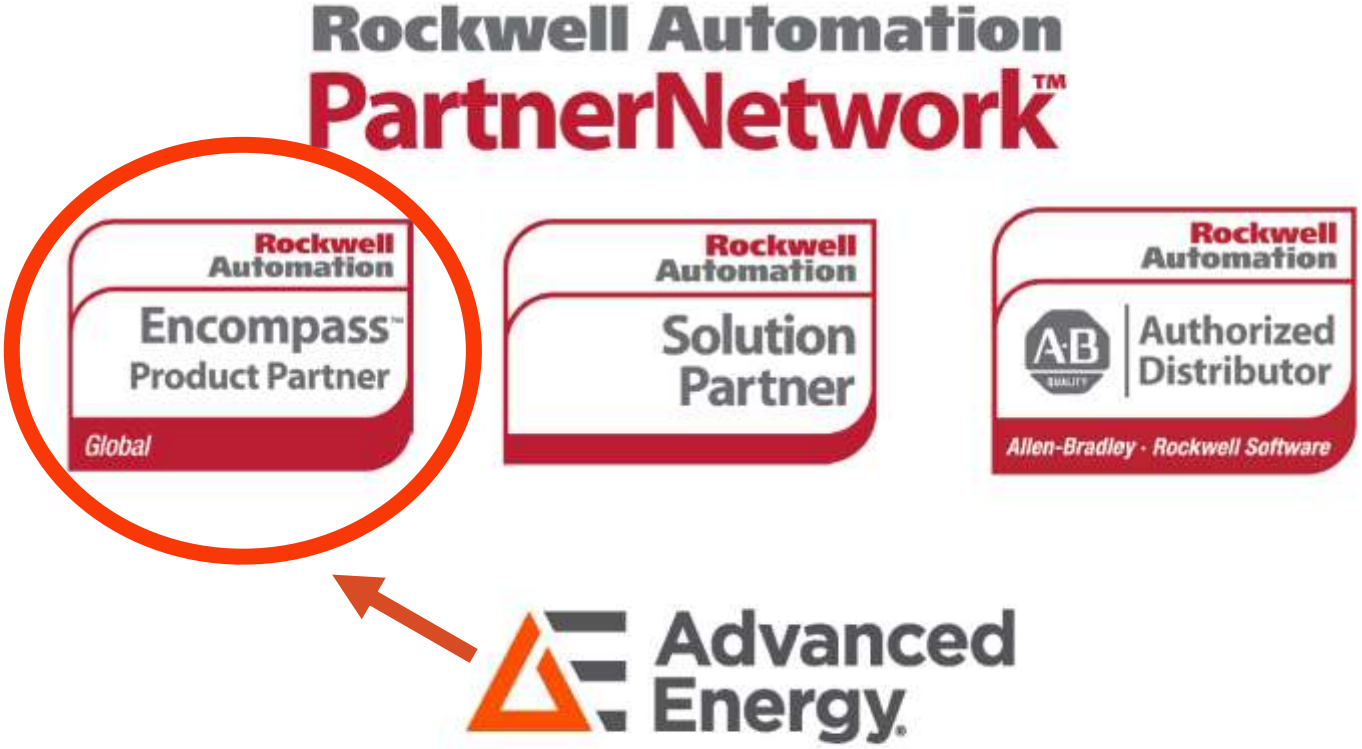
Reliable, Safe, and Secure Networks: Best Practices

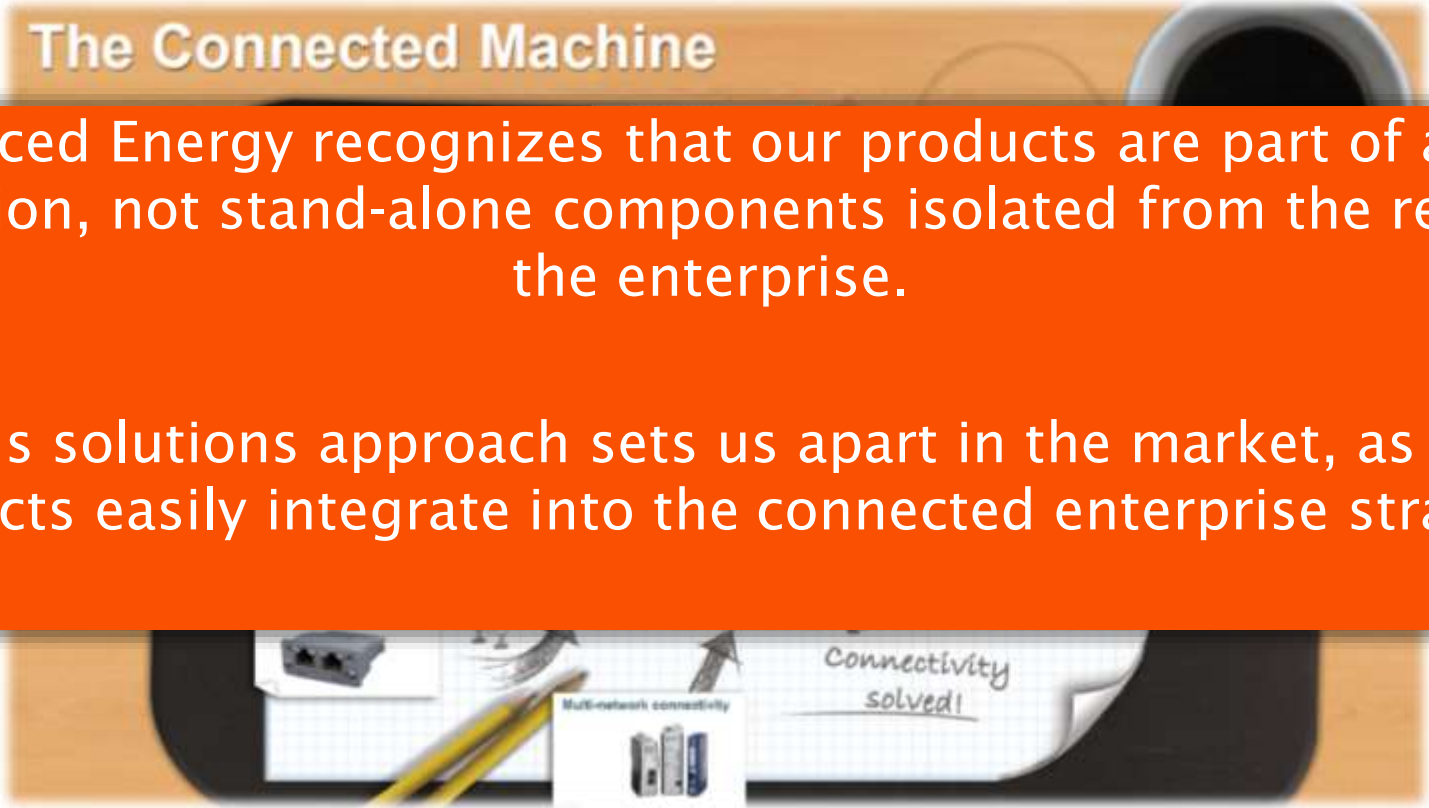
ADVANCED ENERGY AND THE CONNECTED ENTERPRISE

Advanced Energy is a Rockwell Automation® Encompass™ partner.



ADVANCED ENERGY AND THE CONNECTED ENTERPRISE

Advanced Energy embraces best practices utilizing the connected enterprise's reliable, safe, and secure networks.



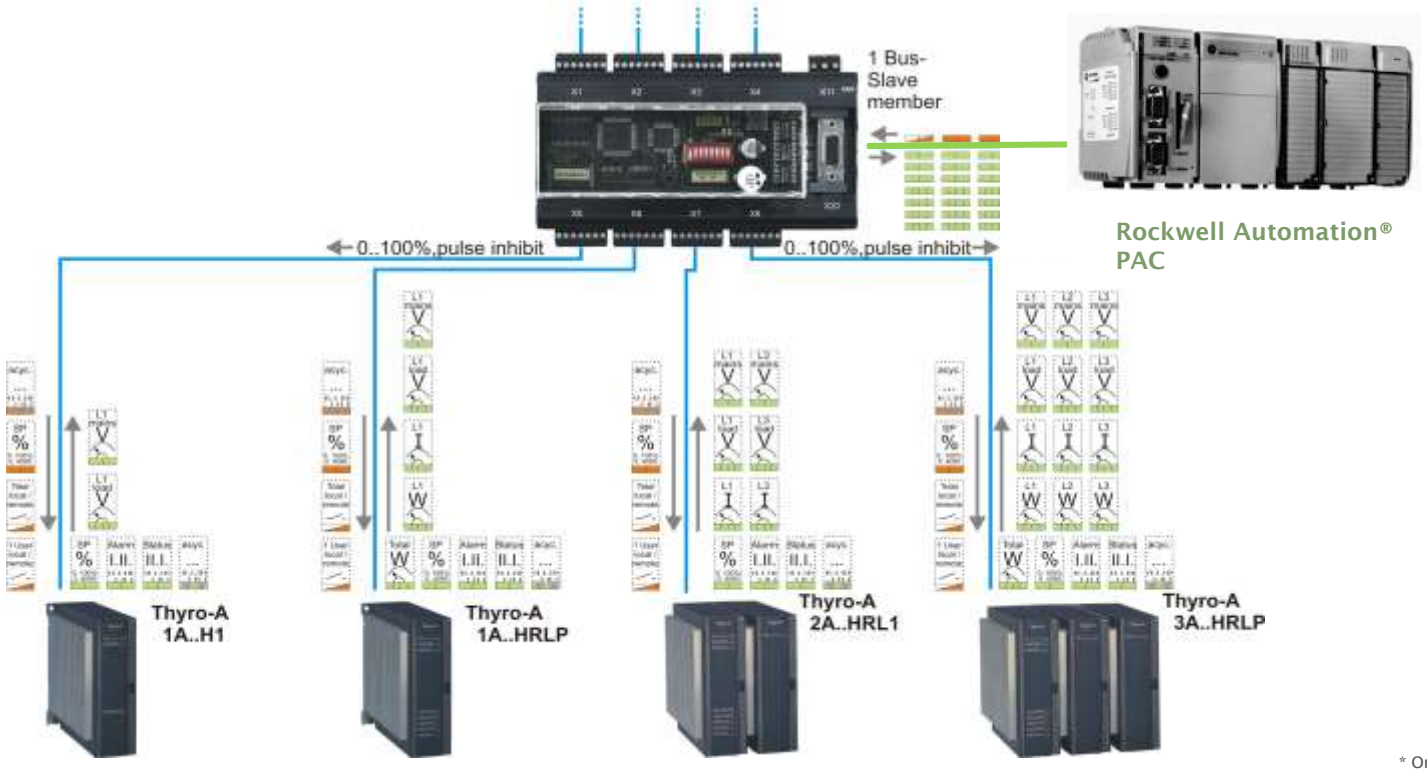
Advanced Energy recognizes that our products are part of a total solution, not stand-alone components isolated from the rest of the enterprise.

AE's solutions approach sets us apart in the market, as AE products easily integrate into the connected enterprise strategy.

THYRO-FAMILY POWER CONTROLLERS: COMMUNICATION AND CONNECTIVITY

Thyro-Family Bus Communication

- Different types of power controllers can be connected to one bus module.



* Only as bus module

THYRO-FAMILY POWER CONTROLLERS: COMMUNICATION AND CONNECTIVITY

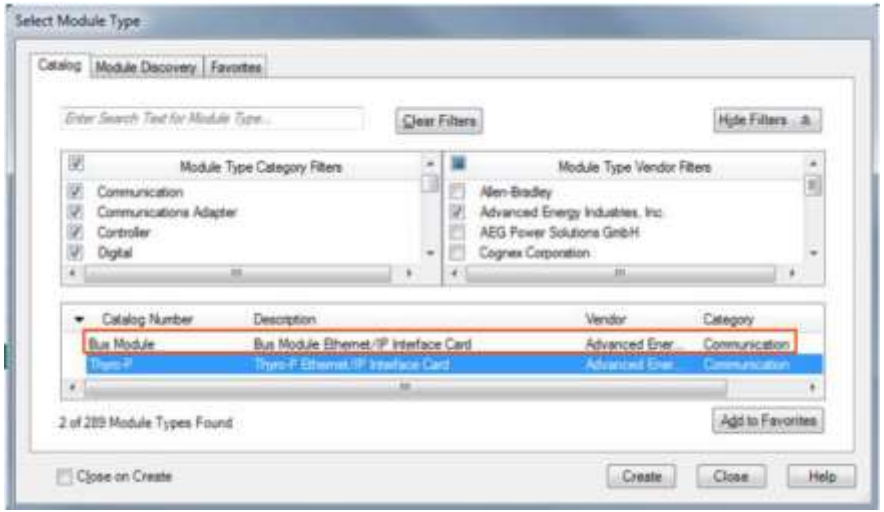
Using the Thyro-Family Power Controller Add-On Profile (AOP)

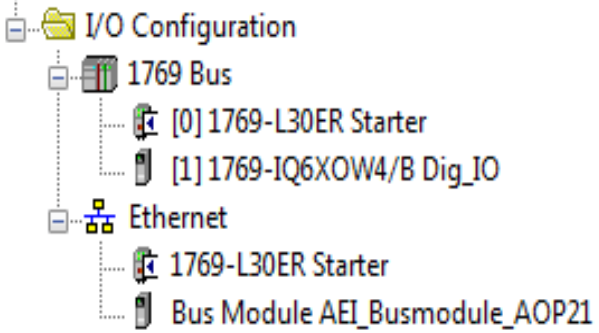
- Configure the rotary switches for EtherNet/IP® and the number of channels in use.
- Using the BOOTP/DHCP application, initialize the Advanced Energy bus module with a user-defined IP address.
  - The BOOTP/DHCP application is provided by Rockwell Automation at the following link: http://www.software.rockwell.com/download/comms/rsnetworx/bootp-dhcp%20server%202.3.2.zip

THYRO-FAMILY POWER CONTROLLERS: COMMUNICATION AND CONNECTIVITY

Using the Add-On Profile (AOP)

- Download and install the Advanced Energy AOP, available on the Advanced Energy website.
- Add the bus module Ethernet/IP interface card to the I/O config.

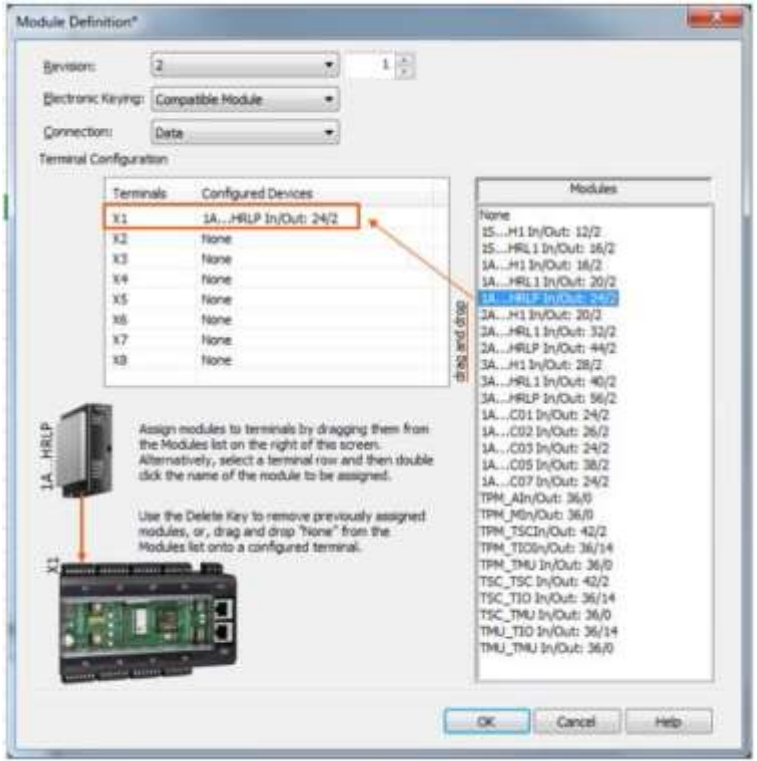




THYRO-FAMILY POWER CONTROLLERS: COMMUNICATION AND CONNECTIVITY

Adding Thyro-Family SCR Power Control Modules to Channels

- Assign the Thyro-Family SCR power control modules to the proper channels.



THYRO-FAMILY POWER CONTROLLERS: COMMUNICATION AND CONNECTIVITY

Best Practices: AOP Tag Data Examples That Can Control the Process and Become Enterprise-Wide Information

AEI_Busmodule_AOP21:I	{...}		AE:BusModule29365E...
AEI_Busmodule_AOP21:I.ConnectionFaulted	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1LoadVoltageL1	228.87695	Float	REAL
AEI_Busmodule_AOP21:I.X1LoadCurrentL1	0.0	Float	REAL
AEI_Busmodule_AOP21:I.X1PowerL1	1.796875	Float	REAL
AEI_Busmodule_AOP21:I.X1MainsVoltageL1	228	Decimal	INT
AEI_Busmodule_AOP21:I.X1SwitchOnTimeT	50	Decimal	INT
AEI_Busmodule_AOP21:I.X1SwitchOnAngleAlpha	0	Decimal	INT
AEI_Busmodule_AOP21:I.X1TotalSetpoint	4096	Decimal	INT
AEI_Busmodule_AOP21:I.X1Fault	2#0000_0000_0000_0000	Binary	INT
AEI_Busmodule_AOP21:I.X1FrequencyOutOfRange	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1SYNCError	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1TemperatureMonitoringTriggered	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1LoadFault	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1FlashValuesInvalid	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1MainsUndervoltage	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1MainsOvervoltage	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1MasterSlaveFault	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1UndervoltageLimit	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1OvervoltageLimit	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1UndercurrentLimit	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1OvercurrentLimit	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1LowPowerLimit	0	Decimal	BOOL
AEI_Busmodule_AOP21:I.X1HighPowerLimit	0	Decimal	BOOL

THYRO-FAMILY POWER CONTROLLERS: COMMUNICATION AND CONNECTIVITY

Best practices in action: manufacturing execution system (MES) and overall equipment effectiveness (OEE)

- Tag data turns into information for the manufacturing execution system (MES). Examples:
  - Power consumption is a major concern in the market. Dirty power, due to power factors less than 1, incurs significant penalties from power companies. From the available data, qualifying and quantifying the positive effects the SCR has on the power grid, i.e., how it can improve PF efficiency, reduce penalties, and ultimately reduce utility costs benefits improves the overall enterprise

  - When the number of times a heating element is turned on and off is reduced, the element spends less time transitioning between hot (expanding) and cold (contracting). The SCR's ability to maintain the element at an even temperature while in operation extends its life.

An SCR power controller's ability to turn on and off at the zero-cross point eliminates the potential RFI, harmonics, and arcing associated with contactors and solid-state relays.

The SCR power controller's ability to provide finer control of the heating element or elements can extend heater life.

CONCLUSION

- Advanced Energy SCR Power Controllers:
  - Provide critical functions for thermal processes
  - Ensure high quality and cost efficiency with:
    - Energy efficiency ($\eta > 99\%$)
    - High accuracy
    - Flexibility
    - Small footprint
  - Provide these benefits through advanced technology and functionality:
    - Operation modes
    - Regulation modes
    - Special energy-efficient modes
    - High power factor

- Advanced Energy and THE CONNECTED ENTERPRISE's reliable, safe, and secure networks provide for ease of integration and use.

THANK YOU FOR YOUR ATTENTION!

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