

# process HEATING

As seen in *Process Heating Magazine*

## What You Need to Know

### About Electrical Heating Control and Monitoring

How to heat only what is needed to a specific temperature and maintain that temperature.

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**H**eating derived from electrical sources is used extensively in industrial processes for thousands of widely varying applications. They include:

- Heating water or other liquids for cleaning parts or to transfer the heat to other environments.
- Increasing the temperature of metal pieces.
- Environmental conditioning.

While the primary goal of these and other applications may vary, overriding objectives include to heat only what is needed, heat it to a specific temperature and maintain that temperature for the period of time required by the application.

Coarse temperature regulation can be achieved by simply turning the circuit that is powering the elements on and off using a switch (mechanical or solid-state relays) or contactor. Adding

a thermostat will improve the consistency of the amount of heat applied, and adding a temperature sensing element (RTD, thermocouple or associated sensor) will further improve regulation of the heating process.

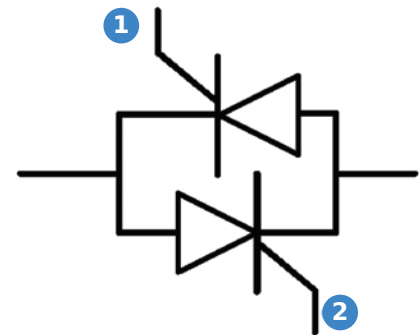
For the most precise and controlled impact on the treated material, the most common method is to control the power applied using silicone-controlled rectifiers (SCRs). These solid-state devices permit the electrical circuit to be turned on and off as needed, allowing only part of the potential power to be applied to the elements (figure 1).

The SCR arrangement commonly used for heating controls combines two diodes with sufficient capacity to switch the full current of the load. One diode allows conduction of the positive half of the alternating current and the other diode allows the negative current to conduct. The extra tails (marked as 1 and 2) shown in figure 1 are trigger signal connections (gates) that tell the SCR to conduct or block that portion of the AC sine wave. This cycling of the circuit on and off can be accomplished several

times each second, thereby allowing the heating element to be energized for only part of each cycle, or for several cycles on and several cycles off.

The method of adjusting the power applied by varying each cycle is commonly referred to as phase-angle firing. By contrast, the approach of allowing full or half cycles to conduct is called burst- or time-proportioned firing.

Either method has advantages and disadvantages. Selecting which method to



**FIGURE 1.** The extra tails shown in the schematic diagram (marked as 1 and 2) are trigger signal connections (gates) that tell the SCR to conduct or block that portion of the AC sine wave.

## ► Temperature Control

employ depends upon the type of heating element being controlled and the need to manage issues such as poor power quality or reduced element longevity.

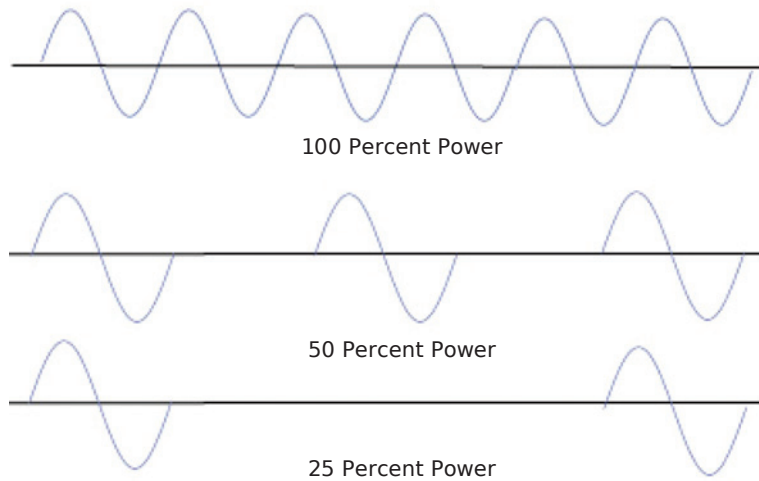
### Phase-Angle Firing

Compared to alternatives, this control

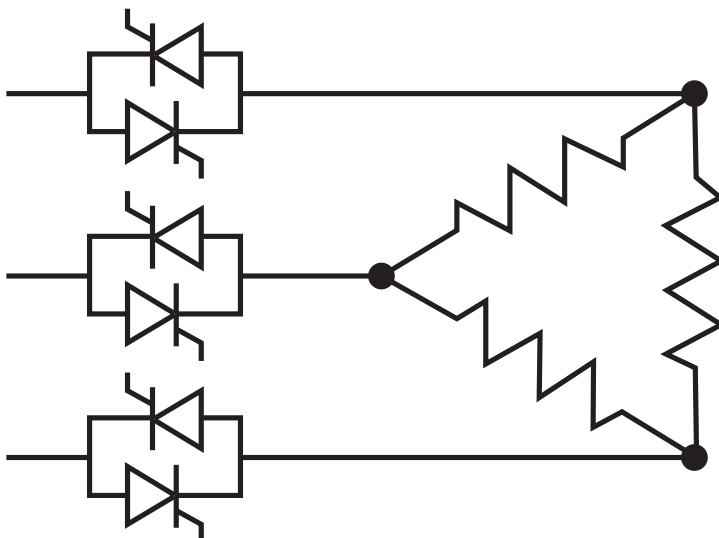
method causes the heating elements to be stressed to a lesser extent because there is little time for the element to cool between cycles. In addition, monitoring the current applied to the circuit is relatively easy using an RMS current sensor.

The installed cost is similar to the

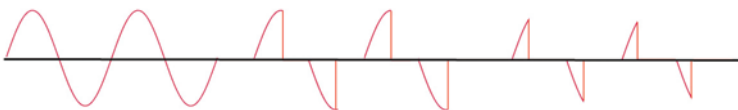
alternative control methods when the load is single phase. When used to control a three-phase load, three SCRs must be used. One drawback to the phase-angle-fired method is that there is a higher degree of harmonic disturbance created in the controlled circuit, with more electrical noise generated. It may require mitigation to protect the supplying transformers from overheating.



Burst-fired controls turn the power on and off only at the zero crossing point where the current and voltage reverse polarity. The on-and-off periods can be as short as one cycle, up to several seconds between bursts of energy applied.



Six SCRs are arranged in a three-phase, phase-angle-fired control scheme powering a delta-connected heating array.



This is the typical current wave shape produced by phase-angle-fired SCRs.

### Time-Proportioned Firing

With this type of switching, the heating elements are energized for some cycles and de-energized for some cycles. The switching is done only at the point where the current crosses the zero point and where the current changes from positive to negative. This results in significant reduction in harmonic content while still providing good temperature regulation.

The burst-firing approach works very well when the heated elements are resistive, but loads like infrared heaters would likely flicker to an unacceptable level. One major issue relating to this flicker is how to measure the current actually being used by the load. It is imperative to know as soon as possible if one element fails. Monitoring the current used by each element in a three-phase delta-connected array is the most logical way to achieve this measurement. Because there are gaps in time when current is not used, standard current transformers or even RMS-reading current transducers will produce an output that will either mirror these gaps or, in the case of an RMS transducer, produce an output signal with excessive ripple.

Therefore, the current measurement signal would need to be filtered and conditioned heavily to produce an average signal directly proportional to the current used. For transformer-coupled loads or to monitor heaters that have variable resistance such as silicon carbide or molybdenum disilicide ( $\text{MoSi}_2$ ) elements, the phase-angle fired SCR method is desirable.



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### Current Sensor Allows Energy Monitoring

One current sensor can monitor burst-fired, SCR-driven loads with little ripple in the output. It was developed following months of planning, circuit design and testing using both computer simulations and actual energized load monitoring.

The microprocessor-based sensor is capable of sampling the primary circuit current magnitude and averaging the current level over time, allowing the sensor output to represent the actual power used by the heaters. This combination of using an analog sensing method derived from a wire-wound, magnetically permeable core surrounding the primary conductor feeding the heating element, integrated with digital-signal processing, produces a reliable measurement technique.

Connecting the sensor output to a programmable logic controller allows the operator to know the amount of power applied to the elements and to confirm the integrity of the element. Connecting the sensor output to a panel meter provides a way to show the power level supplied to the load, allowing an operator to make adjustment decisions during the process. A data-acquisition system can use the sensor reading to

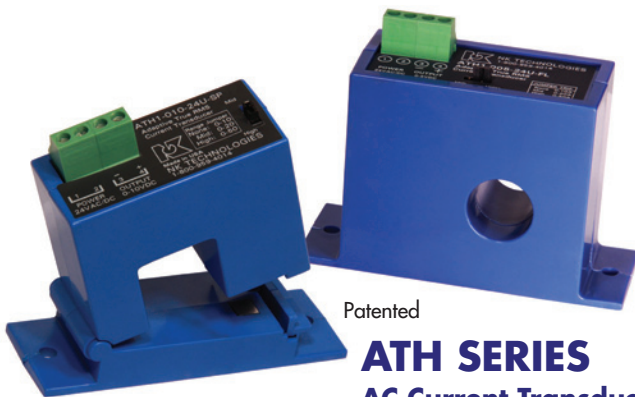
collect power usage over time, allowing reports regarding duration of the process and total time of operation to aid in maintenance scheduling. It also can be used as a tool for cost allocation by a process or department.

Methods to control electrically heated processes are continuously being developed, resulting in energy consumption reduction, higher quality and consistency in the treated materials, and more reliable controllers. Innovations in measuring electrical parameters are catching up, providing the accuracy and reliability demanded by today's processes. ❄

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## AC Current Transducers for Electrical Heating & Monitoring



Patented  
**ATH SERIES**  
AC Current Transducer  
with Time Integration

ATH Series (**patented**) AC Current Transducers are the latest innovation from NK Technologies. Monitoring the current or power controlled by silicon-controlled rectifiers (SCRs) can be a challenge, especially the current used by heaters.

When used to monitor zero-crossing (burst) fired SCRs, the ATH AC Current Transducer will provide an output signal directly proportional to the RMS amperage. Zero-crossing fired controls allow current to flow to the circuit for as short of a time period as one cycle, and off for several cycles. Most current sensors will not work well when there is no current present. This capability is important in case a heating element fails but the process continues operating, which could result in scrapped material.



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