Application Note 1006

Controlling Silicon Carbide Heating Elements with SCR Power Controls

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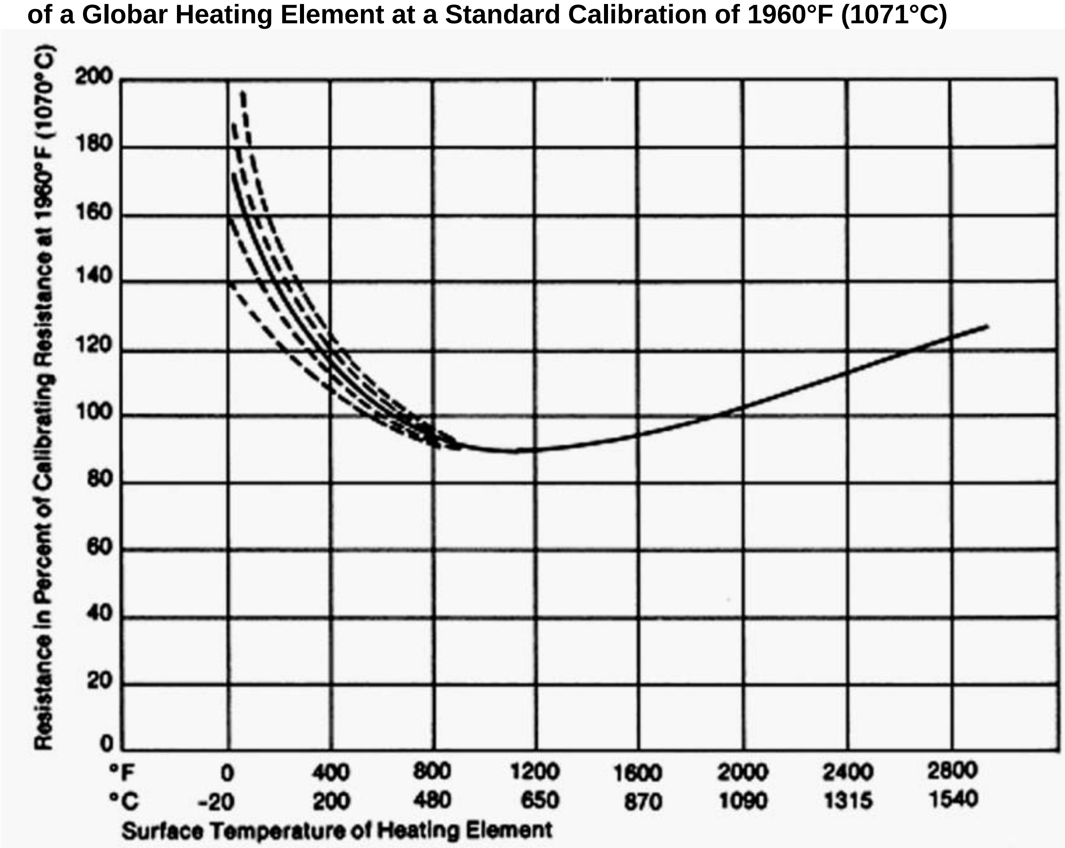
INTRODUCTION

Silicon Carbide Heating Elements (SiC) are ceramic products with a relatively high electrical conductivity as compared to other ceramics. Because they are ceramic they can be extruded or molded to about any size and shape required. They are generally used in high temperature applications.

One of the main advantages of the SiC element is the high hot:cold resistance ratio. The higher the ratio, the more efficient the heating element. Ratio's in the order of 12 or 15:1 and as high as 30:1 are common. The element's resistance changes with both temperature and time.

Due to these special characteristics, care must be taken when sizing an SCR Power Control for use with Silicon Carbide heating elements.

Typical Resistance Temperature Characteristics of a Globar Heating Element at a Standard Calibration of 1960°F (1071°C)



(Chart courtesy of CESIWID Corp.)

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METHODS OF SCR POWER CONTROL

The control system must deal with a wide variation of resistance related to both time and temperature and maintain the power level below the element's specified maximum.

HDR recommends using any one of the three (3) methods described here. Each method has it's own advantages and disadvantages. The user must select based upon his or her own requirements.

1. **Voltage Control with Current Limit:** The SCR Power Control will operate in the phase-firing mode to provide a variable RMS voltage to the heating elements. A RMS Current Limit is provided to limit the current to a preset maximum level to help prevent overpowering the heating element during the low resistance phase of the element.

Advantages
- Lowest cost method

Disadvantage
- Poor Power Factor
- Lowest flexibility

2. **Voltage Control with Power Regulation:** Once again the SCR Power Control will operate in the phase-firing mode but it will utilize a "true" power feedback. This allows the user to maintain the power level to the load constant based upon the command signal level and regardless of the line voltage variations or any load resistance changes. It also has a current limit as a secondary control mode to prevent overcurrenting the power control during the low resistance phase of the elements.

Advantages
- Medium cost method
- Constant power to the load elements
- Automatic (no user interface)

Disadvantages
- Poor Power Factor
- Lower flexibility

300kW Silicon Carbide Power Supply

This power supply was designed and built by Ametek HDR for a Silicon Carbide heating application. It includes a Circuit Breaker, SCR Power Control, Isolation Transformer (in the rear section), Meters, Alarms and Temperature Controls/Limits.

3. **Multi-Tapped Transformer with Voltage Control:** With this method, an SCR Power Control is used to drive the primary of a transformer. The transformer has secondary taps selected to help maintain constant power to the load and maintain a high Power Factor. The phase-fired Power Control is voltage controlled with current limit. The current limit will help prevent overcurrenting the transformer's primary and the SCRs.

Advantages
- High Power Factor
- Highest flexibility

Disadvantages
- Highest cost
- Requires user interface
- Requires more space

SELECTING AN SCR POWER CONTROL

HDR recommends that you always use a Phase-Fired (PF) SCR Power Control. We know of a few installations using Zero-Firing (ZF) for controlling Silicon Carbide elements. However, the thumping sound and the pulsing of the source may be undesirable. In addition, the thumping of the heating elements may reduce their life due to thermal shock.

When selecting the current rating you must consider the lowest resistance of the heating elements. This is the lowest point on the resistance curve (see page 1) and represents the point in which the highest current will occur.

Due to the aging process you should operate at a voltage twice the new element's voltage rating. For example, if the new element voltage rating is 120V, the SCR Power Controller should be operating on 240V. Operating the SCR at a low conduction angle causes the poor Power Factor in control methods 1 and 2. When the element is new the power control will provide 120V out of the available 240V as a maximum and as the element ages the required voltage will slowly increase to 240V. During this low voltage output phase the Power Factor will be low.

In control method 3, the addition of the tapped transformer allows the user to select a tap with a voltage output close to the maximum required by the element and provides a much higher Power Factor. As the element ages and the resistance increases, the user selects the next available higher tap. More taps equal higher Power Factor by allowing the SCR Power Control to operate with the highest possible phase angle.

SELECTING THE TRANSFORMER's TAPS

There is no magic to the number of transformer taps. However, the most widely accepted number is six (6) - five (5) full capacity (FC) and one (1) reduced capacity (RC). The full capacity taps are used during normal operation and the reduced capacity tap (sometimes referred to as the "idling tap") is usually used for keeping the furnace warm during downtime such as on weekends. The higher the number of taps the higher the Power Factor if the operator uses the taps properly. However, more taps do mean more cost.

The following example is for a typical 6 tap transformer with 5 full capacity taps (n) and a nominal voltage of 120V (E).

Note: All voltages and currents have been rounded up.

Maximum Voltage or Tap 6 = $Nom\ E$ x 2

$$Tap\ 6 = 120V\ x\ 2 = 240V$$

$$Tap\ 5 = \sqrt[(n-1)]{\frac{Nom\ E}{Max\ E}}\ x\ Tap\ 6\ Voltage$$

Where n is 5 and

$$\sqrt[(n-1)]{\frac{Nom\ E}{Max\ E}} = \sqrt[4]{\frac{120}{240}} = 0.84$$

$$Tap\ 5 = 0.84\ x\ 240 = 202V$$

$$Tap\ 4 = \sqrt[(n-1)]{\frac{Nom\ E}{Max\ E}}\ x\ Tap\ 5\ Voltage$$

$$Tap\ 4 = 0.84\ x\ 202 = 170V$$

$$Tap\ 3 = \sqrt[(n-1)]{\frac{Nom\ E}{Max\ E}}\ x\ Tap\ 4\ Voltage$$

$$Tap\ 3 = 0.84\ x\ 170 = 143V$$

$$Tap\ 2 = \sqrt[(n-1)]{\frac{Nom\ E}{Max\ E}}\ x\ Tap\ 3\ Voltage$$

$$Tap\ 2 = 0.84\ x\ 143 = 120V$$

$$Tap\ 1 = NomE\ x\ \sqrt{2} = 120\ x\ 0.707 = 85V$$

Once the tap voltages have been selected you must calculate the current rating for each tap. Since the top five taps are full capacity and the bottom tap is reduced, the calculation is slightly different. In both examples a 100kva transformer has been assumed.

The formula for calculating the transformer current (I) is:

$$Single\ Phase \Rightarrow \frac{kVA}{E} = I \qquad\qquad Three\ Phase \Rightarrow \frac{kVA}{E\ x\ \sqrt{3}} = I$$

Single Phase Currents

Tap 6 = kVA/E = I	⇒	100/240 = 417A	Tap 6 = 240V @ 417A FC
Tap 5 = kVA/E = I	⇒	100/202 = 495A	Tap 5 = 202V @ 495A FC
Tap 4 = kVA/E = I	⇒	100/170 = 588A	Tap 4 = 170V @ 588A FC
Tap 3 = kVA/E = I	⇒	100/143 = 699A	Tap 3 = 143V @ 699A FC
Tap 2 = kVA/E = I	⇒	100/120 = 833A	Tap 2 = 120V @ 833A FC
Tap 1 = 833A (same as tap 2)			Tap 1 = 85V @ 833A RC

Three Phase Currents

Tap 6 = kVA/E/√3 = I	⇒	100/240/1.732 = 240A	Tap 6 = 240V @ 240A FC
Tap 5 = kVA/E/√3 = I	⇒	100/202/1.732 = 286A	Tap 5 = 202V @ 286A FC
Tap 4 = kVA/E/√3 = I	⇒	100/170/1.732 = 340A	Tap 4 = 170V @ 340A FC
Tap 3 = kVA/E/√3 = I	⇒	100/143/1.732 = 404A	Tap 3 = 143V @ 404A FC
Tap 2 = kVA/E/√3 = I	⇒	100/120/1.732 = 482A	Tap 2 = 120V @ 482A FC
Tap 1 = 482A (same as tap 2)			Tap 1 = 85V @ 482A RC

INFORMATION REQUIRED TO SPECIFY A TRANSFORMER

The following information is needed prior to specifying a tapped transformer for a Silicon Carbide heating application.

1. *What is the source voltage?*
2. *Is it single or three phase?*
3. *What is the frequency?*
4. *What is the new element's nominal voltage?*
5. *Is the load a 3 or 4 wire connection?*
6. *What is the total load kilowatts?*
7. *What is the preferred number of full capacity taps?*
8. *Is a reduced capacity (idling) tap required?*

CONCLUSION

Silicon Carbide heating elements have special characteristics that require extra attention when specifying an SCR Power Control. With the information provided in this Application Note, you will be able to specify an SCR Power Control or SCR Power Control/Transformer combination for use in a Silicon Carbide heating application.

Typical Shapes of Silicon Carbide Heating Elements
(photo courtesy of Kanthal Corp.)