

## Get More Out of Your Variac

Careful overloading of a Variac® autotransformer can take advantage of many design trade-offs.

For example, the current ratings of all models assume trouble-free operation 24 hours a day, day after day. If a Variac is to be used only 2 hours or less per day, significantly more than rated current can be drawn for that short period. Figure 1 (general specifications) illustrates how up to 10 times the normal rating can be realized.

Also, if the load is frequently switched on and off, the duty ratio of that cycle can permit enough cooling during the off time to allow intentional overloading. A detailed discussion of this consideration appears below.

Finally, certain types of load permit the Variac rating to be increased, as reflected in Variac specifications.

**Match the Variac to the load** To enable the user to get the most out of a Variac autotransformer, General Radio specifies the current rating with two different numbers, rated current and maximum current. Briefly, remember that maximum current can be drawn from the autotransformer only when the output voltage is set near line voltage. Rated current, on the other hand, can be drawn at any setting of the Variac and is the only rating applicable when the overvoltage connection of the Variac is employed.

There are two basic categories of load (linear and non-linear) and the Variac cannot supply as much current at

a mid-range setting as it can near the extremes without overheating. In Figure 3, the sagging dashed line plots the reduction in the current capacity at mid-range. (With an output of 50% of line voltage, there is the greatest internal heating per ampere of output current.)

The straight black line shows the current that a well-behaved constant-impedance load will draw through the Variac as the voltage is decreased from maximum. Note that, even though maximum current is drawn at maximum voltage, the line stays well below the reduced capacity level at mid range. Typical of this kind of load is a heating element.

Unfortunately, all loads don't behave so well, incandescent lights in particular. They react to a decreasing voltage much as shown by the curved solid line. The current they draw drops very little even as the voltage is cut to 50% of maximum. If a load of this type is permitted to draw maximum current at maximum voltage, it will obviously exceed the Variac capacity at mid-range, causing overheating and reduced life. A Variac with larger current capacity must be chosen so the load will not exceed its rated current and thus remain within bounds at mid-range.

So, for many loads, the maximum current rating permits greater performance without risk, while for other common loads, the rated current specification is a neces-

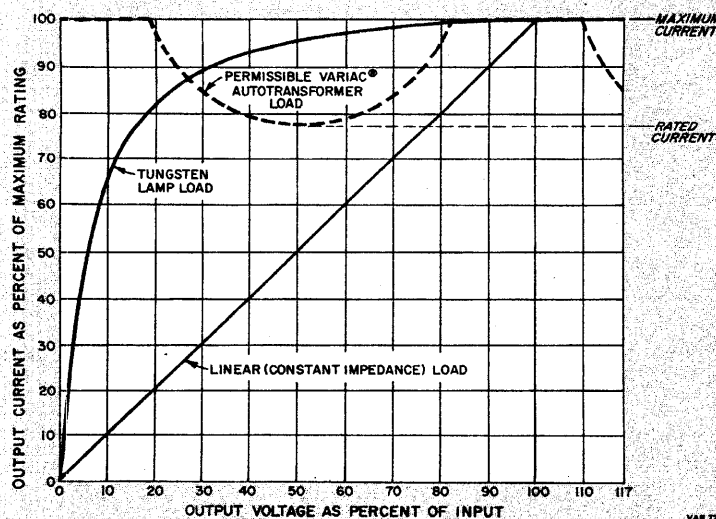


Figure 3. Typical load-current curves.

sary guard against overheating. To limit the specification to but one number would mean either unnecessary caution or undesirable risk; neither would permit full utilization of the Variac capability.

As to the limit on current when the overvoltage connection is used, the dashed line again sags very quickly out beyond the 100%-of-line-voltage point down to the rated-current value. Thus, at 117% of line, the most current that should be drawn is the rated value.

**Effect of duty cycle** When the load is continuously cycled on and off, the rating should be determined as follows. The duty-cycle is defined as the ratio of "off-plus-on" time to "on" time; the rated current can be multiplied by the square root of this ratio to obtain the allowable uprated current. The following examples will illustrate the calculation of permissible overloads for the Type W5 model, whose rated current is 6 amperes.

*Example 1: The load is on for 15 seconds out of every 4 minutes (240 seconds).*

$$\sqrt{\text{duty cycle}} = \sqrt{\frac{240}{15}} = 4$$

**duty-cycle uprated current = 6 A × 4 = 24 A**

From Figure 1 in the "General Specifications," a 15-second overload updates the current by 500% so that

**short-term overload current = 6 A × 5 = 30 A**

Since the lower rating takes precedence, the 24-A limitation imposed by the duty ratio is the maximum current permissible. Note, on the overload curve of Figure 1, the lower curve must be used for models with built-in fuses.

*Example 2: The load is on for 6 seconds out of each minute (60 seconds) over a duration of one-half hour.*

$$\sqrt{\text{duty cycle}} = \sqrt{\frac{60}{6}} = 3.16$$

short-term overload for 30 minutes = 133%

from duty-cycle and 30-minute short-term overload considerations:

**uprated current = 6 A × 3.16 × 1.33 = 24.6 A**

**short-term overload current = 6 A × 7.25 = 42.7 A**

Since the lower rating takes precedence, the 24.6-A limitation imposed by the duty-cycle and 30-minute short-term overload is the maximum current permissible.

**Three-phase load calculations** If the three-phase-load unit is marked with rated line-voltage and current or load-power (kVA), you can easily select a Variac from the foregoing tables.

If, however, the ratings are known only for the individual three elements of the load, you must do some figuring to arrive at the values needed to use the selection tables.

Consider, for example, three heater elements, each rated at 1.4 kVA and 240 V, which are connected in a delta configuration as in Figure 4a. To deliver full power, they must be connected, through a Variac to provide control, to a 240-V line. The current each Variac must supply,  $I_{\text{load}}$ , is  $\sqrt{3}$  times larger than the current in each element of a delta load:

$$I_{\text{load}} = \sqrt{3} \frac{1400 \text{ (VA)}}{240 \text{ V}} = 10.1 \text{ A}$$

In the table of 3-phase 240-V models, the first type listed with adequate "maximum current" rating is the W20HG2. It has two drawbacks, however: It cannot supply overvoltage output (since that means limiting the output to the 'rated current' value), and it is not the most economical selection. The W8G3 Variac is considerably less expensive but cannot supply overvoltage either, for a different reason: It must be wired in a wye

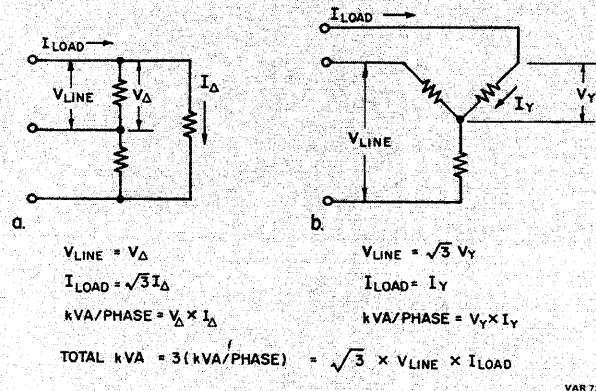


Figure 4. Three-element heater loads.

configuration in which the maximum voltage allowed, 140 V, will be applied to each unit in the assembly, thus preventing added voltage from being developed for the load. To get overvoltage capability, find, in the table, the next model that is wired in an open delta and has adequate "maximum current" rating: The W30HG2. A quick look at larger open-delta assemblies confirms that this is the least expensive choice.

Now consider three heater elements, each rated at 1.0 kVA and 120 V, which are connected in a wye as in Figure 4b. To deliver full power, each element must have 120 V applied. Since the line voltage across a wye is  $\sqrt{3}$  times that across each arm, the needed line voltage is 208 V. Each arm will draw 1000 VA/120 V or 8.3 A from each Variac. From the specifications for three-phase units, select the W5LG3 as having adequate "maximum current" rating. However, the W5LG3 cannot supply overvoltage. If you want the overvoltage feature, you need a W8G3, based on its rated current.

Note that the configuration, open-delta or wye, of the load and the Variac do not have to match.

**Voltage doubling** In normal use, a Variac supplies an output of from 0 to line voltage (or slightly higher when the overvoltage connection is used). On the 240-V (H) models, a provision has been made to apply 120 V and get a 0-to-280-V output. This step-up of 2.33 is accomplished by the application of the high side of the line to either terminal 6 or 7 on the input of the Variac.

Because of the step-up action, the current in the "primary" of the autotransformer is approximately twice the output (brush) current rather than equal to the brush current as it is in the normal connection. Therefore the permissible load current is one half the standard rating for the unit. For example, the rated current for a W10H is 4 A for a 240-V input and 0-to-280-V output. But for a 120-V input and 0-to-240-V output, the rated current for the same unit is only 2 A.