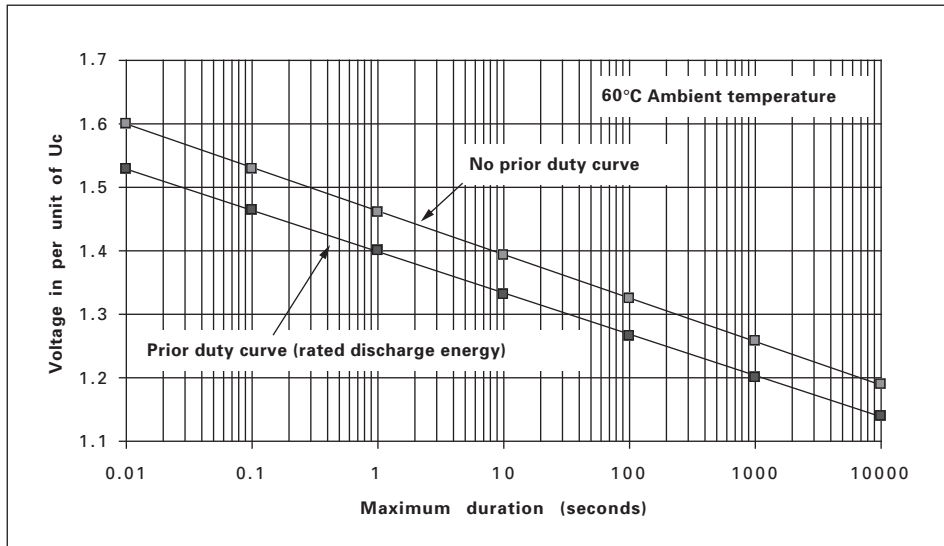


AZG surge arrester rating selection for transmission and station applications



Surge arrester selection

Continuous voltage

Gapless surge arresters must be selected with sufficient steady-state self impedance to withstand the application of line-to-earth power frequency voltages under all system conditions of operation. To assure this, a preliminary selection is based upon choosing an arrester having a "Continuous Operating Voltage", or U_c , that equals or exceeds the normal system *maximum* line-to-earth voltage is made.

Arrester ratings commonly used on three-phase systems

System voltages L-L (kV)		Arrester ratings (kV)	
Nominal	Maximum	Grounded circuits	High impedance/ ungrounded circuits
3.3	3.7	3	-
6.6	7.3	6	9
10.0	11.5	9	12-15
11.0	12.0	9-10	12-15
16.4	18.0	15	18-21
22.0	24.0	18-21	24-27
33.0	36.3	27-30	36-39
47.0	52.0	39-48	54-60
66.0	72.0	54-60	66-84
91.0	100	78-84	90-96
110	123	96-108	120-138
132	145	108-120	132-144
155	170	132-144	162-172
220	245	180-198	204-240
275	300	216-240	258-294
330	362	258-288	294-360
400	420	312-360	-

Power-frequency overvoltages

The second criterion to be met is a condition established by the effectiveness of system grounding. During a single line to-earth fault, under maximum system voltage conditions, the arrester selected should have a "Rating" (U_c) that will not be exceeded by the voltages on the unfaulted phases at the point of arrester application. One must pay particular attention to systems having low coefficients of grounding, ungrounded systems, and systems that may become ungrounded under certain conditions of operation. This second voltage consideration, although mandatory for older technology gapped silicon carbide arresters, may be modified for certain system conditions as long as the application does not violate the selected AZG arrester's "Temporary Overvoltage Capability (TOV)".

Temporary system conditions resulting in *sinusoidal power-frequency voltages* that exceed arrester "Continuous Operating Voltage, (U_c)" or even "Arrester Rating, (U_c)" can be allowed by considering the permissible magnitude and duration of these overvoltages (including the full time of system back-up protection), with appropriate allowances made for any recent discharge energies. For systems that are ungrounded, high impedance on resonant grounded one must investigate the magnitude and duration of the voltage impressed on the arrester. Arresters, if used on an isolated system neutral, should be taken as an application using these same considerations.

Although intuitively one may desire to extend the TOV curve for times exceeding 10,000 seconds (2.8 hours) doing so must

balance the risk of a re-occurrence of the original condition over such an extended time. A re-occurrence would represent a second contingency without allowances for such conditions.

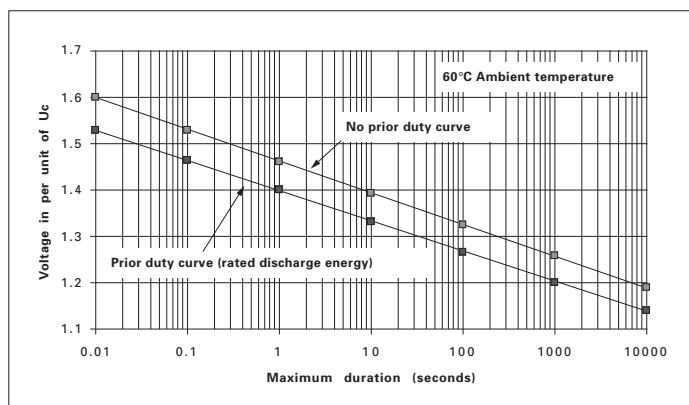
Energy considerations

The third selection criterion determines the particular type of AZG arrester (line discharge class 2, 3, or 4) based upon the switching surge energy that the arrester will be expected to discharge in a specific application. Lightning is rarely, if ever, an energy consideration in shielded substation environments and may be neglected.

The significant energy an arrester may be expected to discharge is that stored in the power system generated by switching overvoltages. The total discharged "switching surge energy" is a complex function of the non-linear interaction between the arrester's volt-ampere characteristic and the system electrical parameters. The effects of capacitor banks, multiple or long transmission lines and breaker switching operations may be predicted through the transient network analyzer (TNA) or by digital programs (such as EMTP) that will accurately model system and arrester dynamic behavior. Eaton engineers are available to make such studies.

Computer modeling will predict arrester discharge energies and discharge current magnitudes that can be compared to the AZG2, 3, and 4 arresters' capabilities. Frequently energy selections are based simply upon the transmission line parameters of surge impedance, line length, and an assumed number of switching operations within a given period. IEC 99-4, in paragraph 7.4.2 and Annex E, outlines the line discharge characteristics associated with the standard IEC discharge classes. One may reduce arrester switching surge duty by increasing the arrester rating (U_c). A small increase in rating will result in a substantial decrease in absorbed energy and the associated discharge current. Past experience in known circuit configurations may be the best guide in class selection where a sophisticated study is not warranted. Arresters applied for lightning impulse protection alone may be selected without regard to energy handling capabilities; noting however, that if increased insulation protection is desired it may be obtained by selecting an AZG arrester having the same rating (U_c), but of a higher line discharge class.

Temporary overvoltage capability of VariSTAR AZG surge arresters



Summary

Using this method of selection will result in the minimum arrester rating necessary to survive system power frequency voltage conditions. Increasing rating above this minimum will result in a greater arrester tolerance for system voltage excursions; but, if rating is increased unnecessarily, compromised insulation protection will result. Rating selection is an engineering balance of arrester survivability against the insulation protection afforded to the equipment. An arrester having just sufficient power-frequency voltage withstand is preferred - it is the best economic choice and will provide optimum insulation protection.

Simple and direct insulation coordination

AZG arresters provide insulation protection due to the inherent non-linear electrical characteristics of metal oxide varistors. The insulation protection afforded by gapless metal oxide arresters is a function of the volt-ampere characteristic of the series connected varistor disks and is also dependent on the time-to-crest of the current discharge. Because AZG metal oxide arresters have a well defined current and voltage relationship obtained by direct measurement, insulation coordination of AZG surge arresters is both simple and direct.

An insulation coordination analysis of the protection afforded by an arrester (after making an initial arrester choice based on system voltages as outlined in the preceding section) is normally made by comparing selected arrester residual voltages to the three known

voltage withstand points of the protected equipment's insulation: the chopped wave, full wave, and switching surge insulation test values.

To make an insulation coordination study, obtain the appropriate AZG surge arrester residual voltages from the Eaton catalog. For a specific application, the calculation of the recommended protective margins at the three equipment test points will reveal the superior protection afforded by AZG surge arresters, especially to oil-filled equipment. One finds that the protective margins (protective ratios) at each insulation coordination point are approximately equal; that is, the shape of the voltage-time protective characteristic of the arrester closely matches the shape of the equipment's tested insulation withstand. AZG surge arresters protect equipment across the entire lightning and switching surge overvoltage spectrum with "balanced margins of protection".

Insulation coordination

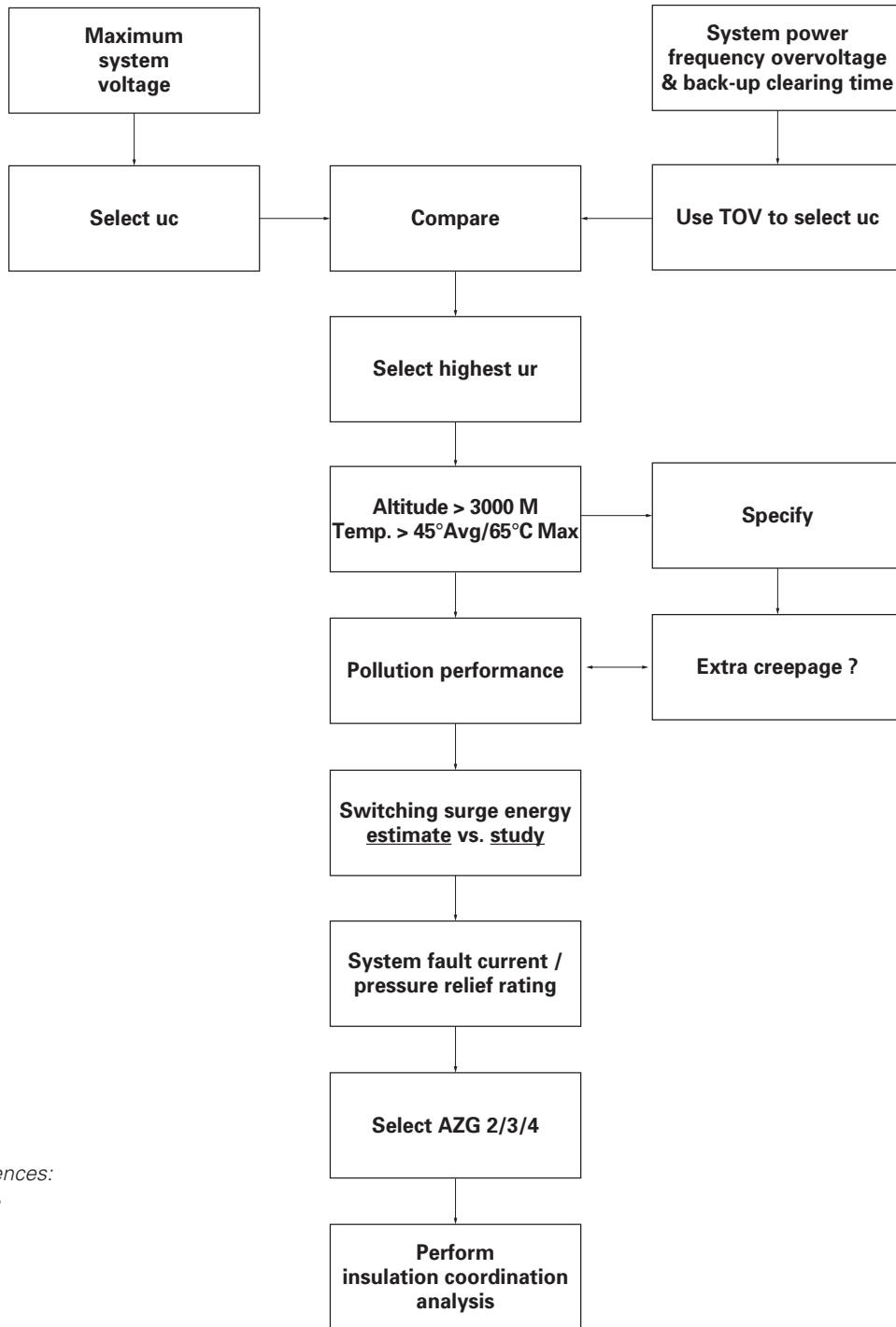
Equipment insulation withstand	Arrester residual voltage	Recommended minimum margin (protective ratio)
Chopped wave		
<ul style="list-style-type: none"> • 1.15 x BIL for paper/oil insulation • 1.0 x BIL for solid or SF6 insulation 	Steep current impulse voltage at nominal discharge current	20% (1.2)
Full wave BIL		
<ul style="list-style-type: none"> • 1.0 x BIL 	Lightning impulse residual voltage at nominal discharge current	20% (1.2)
Switching surge		
<ul style="list-style-type: none"> • 0.83 x BIL 	Switching impulse residual voltage at: <ul style="list-style-type: none"> • 500 A for line discharge class 2 arresters • 1000 A for line discharge class 3 arresters • 2000 A for line discharge class 4 arresters 	15% (1.15)

* Percent margin = 100 x (I - A)/A, or alternatively –
Protective ratio = I/A

Where, I = the equipment insulation withstand. A = the arrester residual voltage (protective level).

The "Recommended Minimum Margins" shown are after allowances for any circuit configurations (usually separation distance) or other installation specific conditions that may compromise the arrester's ability to provide over-voltage protection.

Arrester rating selection



Recommended References:
 ANSI/IEEE Std C62.22
 IEC 99-5

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

Eaton's Power Systems Division
 2300 Badger Drive
 Waukesha, WI 53188
 United States
 Eaton.com/cooperpowerseries



© 2017 Eaton
 All Rights Reserved
 Printed in USA
 Publication No. TD235022EN

Eaton is a registered trademark.
 All trademarks are property
 of their respective owners.

For Eaton's Cooper Power series surge
 arrester product information
 call 1-877-277-4636 or visit:
 www.eaton.com/cooperpowerseries.