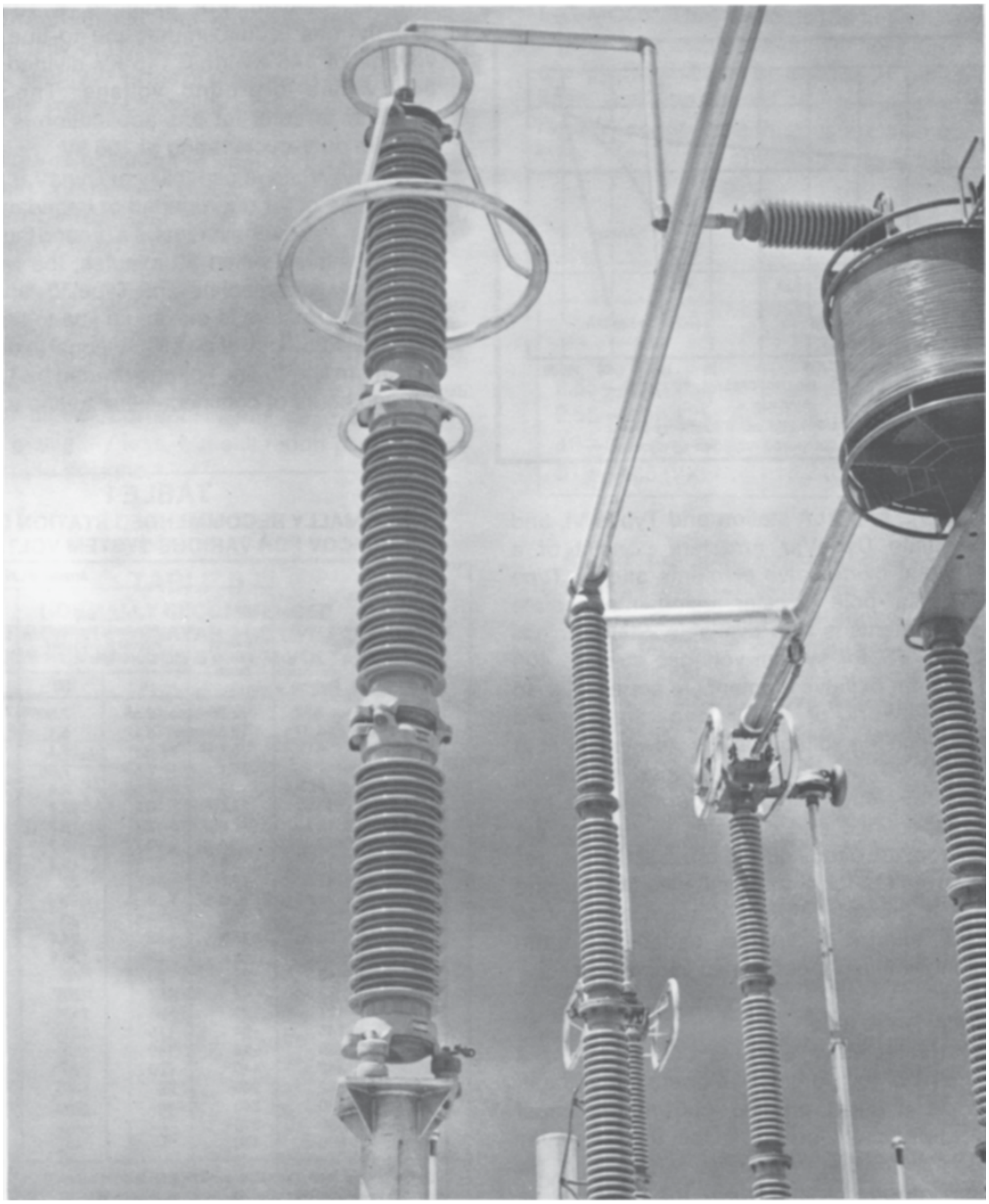
APPLICATION GUIDE
DynaVar Metal-Oxide
Surge Arrester



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Arrester Description

The Ohio Brass DynaVar arrester is significantly different in concept from previous arresters using gaps in series with silicon carbide valve blocks. The extreme improvement in nonlinearity of metal-oxide varistor valve elements (Figure 1) allows up to full operating voltage to be continuously applied to the valve element, which cannot be done with silicon carbide.

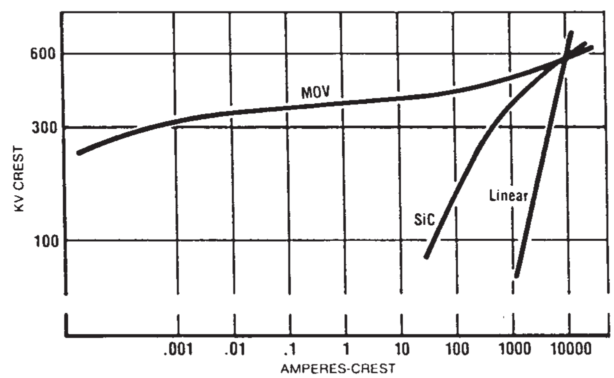


FIGURE 1
DynaVar 209 MPR-258 valve elements and a linear resistor compared on a 345-kV system.

Types VN, VL, and VLA station and Types VI, and VIA intermediate DynaVar arresters consist of a column of metal-oxide valve elements only. A Type VR gapless riser-pole arrester, using intermediate class valve elements is also available. Station class DynaVar Type VS, for system voltages through 400 kV, has a column of valve elements in series with an impedance network of linear capacitance and resistance to limit the voltage on the valve element to approximately 90 percent of the total operating voltage. A heavy-duty gap is in parallel with this additional impedance and operates to remove the impedance from the circuit during arrester discharge.

Type VX arresters for system voltages 500 kV and above have a greater volume of valve element to increase the energy dissipation capability of the arrester, along with a gapped series impedance.

Selection of Arrester Size

Since the arrester valve element carries all, or a substantial part of the continuous operating voltage, and conducts a small grading current, the most important application criterion for the DynaVar arrester is the maximum voltage which can be continuously applied. Therefore, the arrester is described by its maximum continuous operating voltage or MCOV. Each arrester also carries a conventional duty-cycle rating for convenience. The normal MCOV values and corresponding duty-cycle ratings are those adopted for ANSI Standard C62.11 by the IEEE Surge Protective Devices Committee.

For conventional effectively grounded neutral systems on which a fault is expected to initiate a circuit breaker operation, the DynaVar arrester with MCOV equal to maximum line-to-neutral voltage is suitable, regardless of grounding coefficient at the arrester location. For example, a 138 kV system usually has a maximum line-to-line continuous voltage of 145 kV rms. 145 kV divided by $\sqrt{3}$ gives 84 kV line-to-ground voltage. The appropriate DynaVar arrester for this application is the DynaVar 84, with duty-cycle rating of 108 kV.

The overvoltage capability of DynaVar can be taken advantage of for ungrounded or impedance grounded systems. For such systems, if a ground fault is expected to be removed within 30 minutes, the recommended MCOV for intermediate and Type VL and VN station DynaVar arresters is maximum line-to-line voltage divided by 1.25. Use of an MCOV equal to or greater than maximum line-to-line voltage divided by 1.11 allows up to 2000 hours of continuous line-to-line voltage on the

TABLE I
NORMALLY RECOMMENDED STATION DYNAVAR MCOV FOR VARIOUS SYSTEM VOLTAGES

System L-L Voltage kV		Arrester MCOV (kV)				
		Grounded Neutral Circuits	Temporarily Ungrounded, Impedance Grounded or Ungrounded Circuits Types VL, VN		Temporarily Ungrounded Impedance Grounded or Ungrounded Circuits Type VS	
Nominal	Maximum		(1)	(2)	(3)	(4)
2.4	2.52	2.55	2.55	2.55		
4.16	4.37	2.55	5.1	5.1		
4.8	5.04	5.1	5.1	5.1		
6.9	7.25	5.1	7.65	7.65		
8.32	8.74	5.1	7.65	8.4		
12.0	12.6	7.65	10.2	12.7		
12.47	13.1	7.65	12.7	12.7		
13.2	13.9	8.4	12.7	12.7		
13.8	14.5	8.4	12.7	15.3		
20.78	21.8	12.7	19.5	22		
22.86	24.0	15.3	19.5	22		
23.0	24.2	15.3	19.5	22		
24.94	26.2	15.3	22	24.4		
34.5	36.2	22	29	36.5		
46	48.3	29	39	48		
69	72.5	42	57	70	52	57
115	121	70	98	115	88	98
138	145	84	115	131	106	115
161	169	98	140	152	131	140
230	242	140	209	220	180	209
345	362	209	—	—	—	—
400	420	245	—	—	—	—
525	550	318	—	—	—	—
765	800	470	—	—	—	—

(1) For normal duty. Line-to-ground fault up to 30 minutes.
(2) For severe duty. Line-to-ground fault up to 2000 hours.
(3) For normal duty. No anticipated high ambient temperatures or discharge duty prior to ground fault.
(4) For severe duty. Anticipated high ambient temperatures and maximum energy discharges immediately preceding the ground fault.

arrester. For normal ungrounded Type VS or VX station arrester application, arrester MCOV is maximum system line-to-line voltage divided by 1.4. Table I shows normally recommended station DynaVar arrester application for various system voltages and grounding practice. Table II shows normally recommended intermediate DynaVar and DynaVar VR riser pole arresters for various system voltages.

Line Switching Surge Durability

Unlike current-limiting gap arresters, the switching surge durability of DynaVar arresters can usually be expressed simply in terms of dissipated energy. Table III shows the energy capability in kilojoules per KV of MCOV.

These figures assume the energy discharge takes place within one minute. Discharge of the maximum energy can be repeated many times with sufficient cooling time to keep arrester temperature at reasonable levels.

The indicated current levels are not an arrester limitation, but are related to the indicated energy capability. They are seldom exceeded during line discharges, but cable and capacitor bank discharges may be of higher current. In this case the energy capability is slightly less, but still much greater than silicon carbide designs.

TABLE II
NORMALLY RECOMMENDED INTERMEDIATE DYNAVAR AND DYNAVAR VR MCOV FOR VARIOUS SYSTEM VOLTAGES

System L-L Voltage kV		Arrester MCOV—kV		
		Grounded Neutral Circuits	Ungrounded Circuits	
Nominal	Maximum		(1)	(2)
2.4	2.52	2.55*	2.55*	2.55*
4.16	4.37	2.55*	5.1 *	5.1 *
4.8	5.04	5.1 *	5.1 *	5.1 *
6.9	7.24	5.1 *	7.65*	7.65*
8.32	8.73	5.1 *	7.65*	8.4*
12	12.6	7.65*	10.2*	12.7*
12.47	13.1	7.65*	12.7*	12.7*
13.2	13.9	8.4*	12.7*	12.7*
13.8	14.5	8.4*	12.7*	15.3*
20.78	21.8	12.7*	19.5*	22*
22.86	24	15.3*	19.5*	22*
23	24.2	15.3*	19.5*	22*
24.94	26.2	15.3*	22*	24.4
34.5	36.2	22*	29*	36.5
46	48.3	29*	39	48
69	72.5	42	57	70
115	121	70	98	—
138	145	84	—	—

Intermediate DynaVar, metal top, available in all sizes.
Intermediate DynaVar, porcelain top, available in 19.5 kV MCOV and below.
(1) For normal duty. Line-to-ground fault up to 30 minutes.
(2) For severe duty. Line-to-ground fault up to 2000 hours.
* Available in VR design.

Accurate calculation of the discharge energy possible in a given application may require modeling of all pertinent system components in a computer study, but this is seldom necessary. Calculations based on the conservative assumption that the entire line length is charged to maximum surge voltage are easily made, and the values obtained seldom exceed the considerable energy capability of the DynaVar arrester.

Figures 2-5 are based on such calculations for 242 kV through 800 kV systems, using arresters of one p.u. L-G MCOV. They indicate the line charge voltage for a given line length which will not cause the DynaVar energy capability to be exceeded. Single and parallel lines are considered. Single discharge and two rapidly repeated discharges are also considered; the latter might occur on line reclosure failure.

TABLE III

Arrester MCOV (kV)	Maximum Energy Discharge Capability (kJ/kV MCOV)
2.55—98 (VI)	3.4 (Currents 650 A or less)
2.55—39 (VL, VLA)	4.9 (Currents 1.0 kA or less)
42—245 (VS, VN)	8.9 (Currents 1.5 kA or less)
318—485 (VX)	16.2 (Currents 2.7 kA or less)

As an example, consider the ANSI C62.11 line discharge test parameters for a 362 kV system. Line length is 200 miles; surge impedance is 350 ohms; and p.u. charge is 2.6. Figure 3 shows at 200-mile length the charge voltage can be as high as 3.7 p.u. without damage or, conversely, the line length could be more than 400 miles at 2.6 p.u. charge.

Thus, a 209 kV MCOV DynaVar arrester on a 362 kV system can withstand twice the energy per discharge as that resulting from the ANSI test. At all other system voltages, this margin is even greater.

Surges Transferred Through Transformers

In the past, some utilities carfully selected arresters for both high- and low-side transformer winding protection in order to prevent high-energy switching surges on the high-voltage circuits from being discharged by arresters on the low-voltage windings. With DynaVar metal-oxide arresters, this application is simplified due to the high nonlinearity of the blocks. Now it is necessary only to select a low-side arrester with discharge voltage four percent higher than the arrester on the high side, with both high- and low-side arrester discharge voltage expressed in per unit of system line-to-ground voltage. For instance, if a VS-209 is used on the high side of a 345/138 kV transformer (1 p.u.), a VS-88 on the low-side

242kV (230kV Nom.) System
Z = 400Ω
DynaVar 140 MCOV

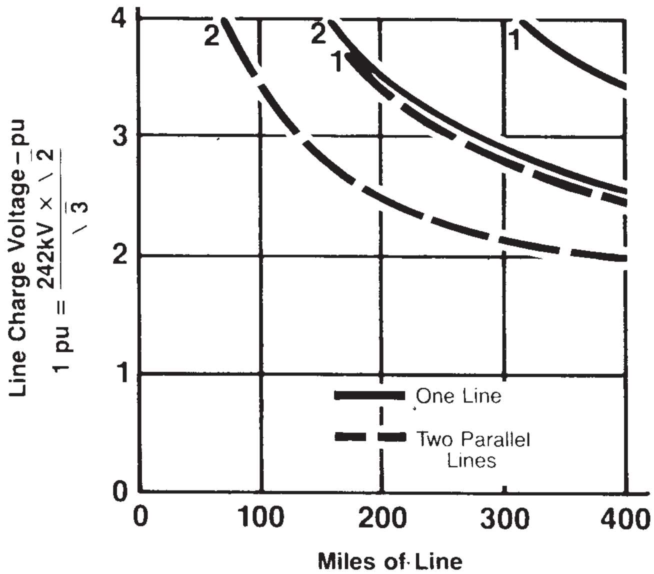


FIGURE 2

A 242-kV system – line discharge capability.

1 - one discharge
2 - two discharges within one minute

Indicated duty may be repeated with adequate cooling (more than one minute) between discharges.

362kV (345kV Nom.) System
Z = 350Ω
DynaVar 209 MCOV

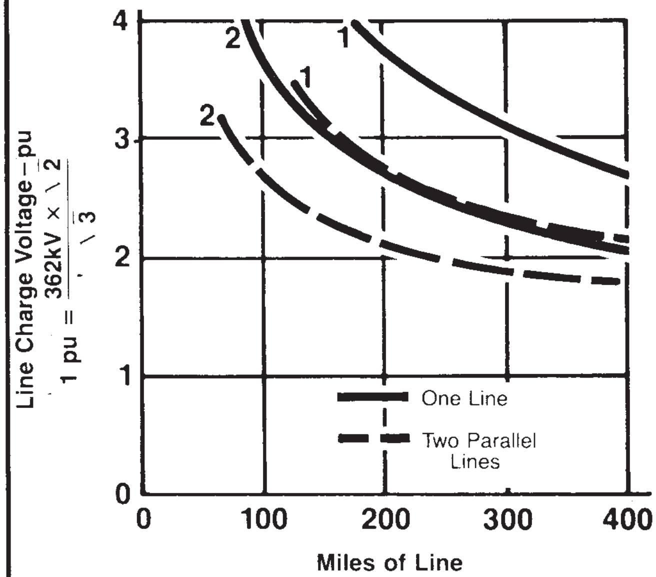


FIGURE 3

A 362-kV system – line discharge capability.

1 - one discharge
2 - two discharges within one minute

Indicated duty may be repeated with adequate cooling (more than one minute) between discharges.

550kV (525kV Nom.) System
Z = 325Ω
DynaVar 318 MCOV

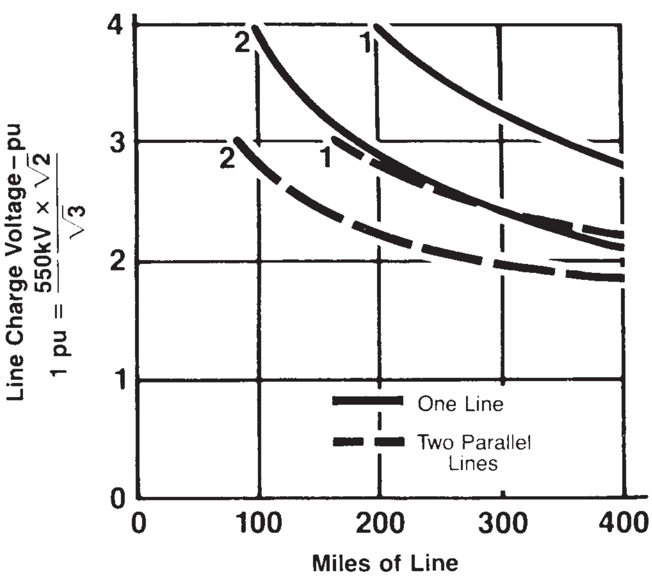


FIGURE 4

A 550-kV system – line discharge capability.

1 - one discharge
2 - two discharges within one minute

Indicated duty may be repeated with adequate cooling (more than one minute) between discharges.

800kV (765kV Nom.) System
Z = 300Ω
DynaVar 470 MCOV

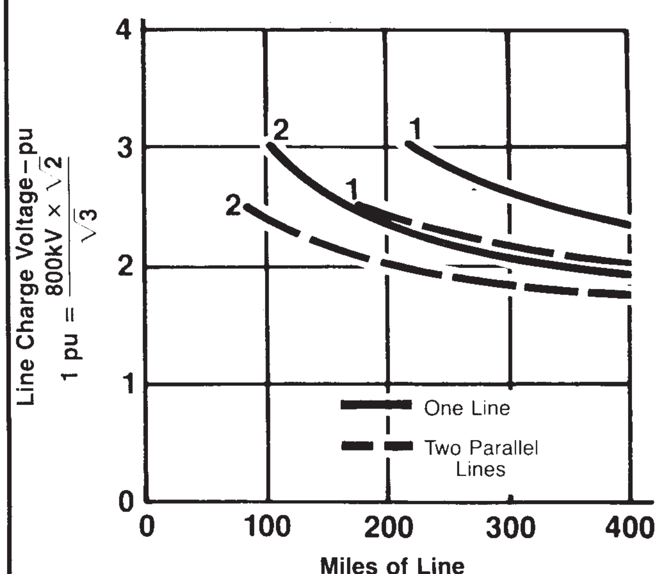


FIGURE 5

An 800-kV system – line discharge capability.

1 - one discharge
2 - two discharges within one minute

Indicated duty may be repeated with adequate cooling (more than one minute) between discharges.

(1.05 p.u.) would avoid surge transfer. Or a VN-84 on the low side would have eight percent higher discharge voltage than the VS-84, and also avoid surge transfer.

Utilities can be assured that low-side arresters will not be subjected to dischages in excess of their energy capabilities if conservative guidelines are followed. For autotransformers, check if discharging the high-side transmission line through the low-side arrester will result in an energy discharge in excess of rating.

Numbers in Figure 7 are based on the assumption that only the low-side arrester operates, and transformer inductance is neglected. The autotransformer inductance would make actual low-side operations less severe. Inductance would probably also cause the high-side arrester to operate on $+\frac{di}{dt}$. For proper application, the discharge energy level (kJ/kV) should be equal to or less than the maximum capability in kJ/kV MCOV of the arrester shown in Figure 6. Figure 7 assumes the high-side line has the length and charge voltage required for the transmission line discharge test in ANSI C62.11. The discharges would be less severe for shorter lines or lower charge.

Where the possibility of low-side arrester duty in excess of energy rating exists, such as in all the 138 kV examples in Figure 7, use a low-side arrester MCOV four percent higher than the high-side arrester MCOV times the transformer turns ratio, assuming the same arrester type. Where different arrester types are considered for high- and low-sides, compare switching surge discharge voltage rather than MCOV.

$$\text{Minimum } MCOV_L = 1.04 \times MCOV_H \times N$$

Where: $MCOV_L$ = low-side MCOV

$MCOV_H$ = high-side MCOV

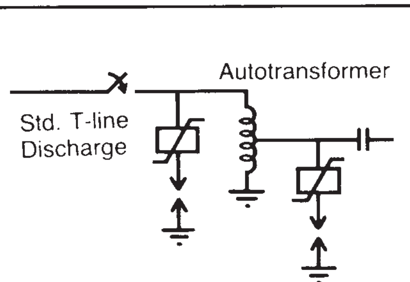
N = turns ratio, L/H

(The 1.04 constant is appropriate for Type VS, VN, and VX arresters. Other manufacturers may have different values for this constant.)

For example, assume a 525 kV/138 kV autotransformer uses a VX-318, 318 kV MCOV, high-side arrester and the 525 kV transmission line discharge can be severe. Use of a VS-88 rather than 84 kV MCOV low-side arrester will assure high-side operation also on any transferred surge where low-side duty would be otherwise severe. A VN-84 gapless arrester on the low side would also have discharge voltage high enough to avoid surge transfer.

DynaVar arresters used on ungrounded circuits and subjected to transferred surges should be chosen from the severe-duty columns of Table I for normally recommended DynaVar arresters. For delta-to-wye surge transfers, the arresters normally used on the wye-connected side are adequate.

TRANSFERRED ANSI C62.11 TRANSMISSION LINE DISCHARGE ENERGY CAPABILITY FOR DYNAVAR VS, VN



System kV	Arrester MCOV* kV	Maximum Discharge Energy Capability kJ/kV MCOV
138	84	8.9
230	140	8.9
345	209	8.9
520	318	16.2
765	470	16.2

*Maximum continuous operating voltage, line-to-neutral, applied to the arrester.

FIGURE 6

ANSI C62.11 TRANSMISSION LINE DISCHARGES CALCULATED FOR TRANSFER THROUGH AUTOTRANSFORMER TO LOW-SIDE DYNAVAR ARRESTER

Transformer kV	High-side Arrester				Low-side Arrester			
	Amps	kV	kJ	kJ/kV MCOV	Amps	kV	kJ	kJ/kV MCOV
345/138	950	441	880	4.2	2200	185	855	10.2
345/230	950	441	880	4.2	1360	301	860	6.1
525/138	720	664	1100	3.5	2200	185	935	11.1
525/230	720	664	1100	3.5	1500	301	1038	7.4
525/345	720	664	1100	3.5	1050	441	1065	5.1
765/138	1100	987	2500	5.4	4000	193	1780	21.2
765/230	1100	987	2500	5.4	2900	312	2080	14.8
765/345	1100	987	2500	5.4	2100	462	2230	10.6
765/525	1100	987	2500	5.4	1480	693	2260	7.4

FIGURE 7

Shunt Capacitor Bank and Cable Application
Discharge currents from capacitor banks and cables can be higher than those from overhead lines. Under these circumstances, the arrester energy capability may be less than previously shown.

However, assuming no switching malfunction or restriking, Figures 8 and 8A apply to capacitor banks and cables on grounded neutral systems using normally recommended MCOV station arresters. This is true for all source reactances normally encountered. Thus, almost any practical shunt capacitor bank size or cable length can be tolerated if no restrikes occur.

SHUNT CAPACITOR BANKS

(DynaVar MCOV = Maximum System L-G Voltage)

MCOV = 2.55 to 39 kV:
3ϕMVAR = 1.5 × Max. System L-L Voltage (kVrms)

MCOV = 42 to 245 kV:
3ϕMVAR = 2.7 × Max. System L-L Voltage (kVrms)

MCOV = 318 to 485 kV:
3ϕMVAR = 5.4 × Max. System L-L Voltage (kVrms)

FIGURE 8

For example, a 145 kV (138 kV nominal) shunt bank protected by 84 kV MCOV DynaVar station arresters can be as large as: 2.7 × 145 = 391 MVAR.

A 145 kV cable of 0.4 microfarad/mile, using the same 84 kV MCOV DynaVar arresters, can be as long as:

$$\frac{7000}{145 \times 0.4} = 120 \text{ miles}$$

CABLES

(DynaVar MCOV = Maximum System L-G Voltage)

MCOV = 42 to 245 kV:

$$\textbf{Cable Miles} = \frac{7000}{\text{Max. System L-L Voltage (kVrms) X}\mu\text{F/mile}}$$

MCOV = 318 to 485 kV:

$$\textbf{Cable Miles} = \frac{14\,300}{\text{Max. System L-L Voltage (kVrms) X}\mu\text{F/mile}}$$

FIGURE 8A

If a restrike does occur, then the arrester current and energy will increase markedly. Figure (9) gives formulas for approximating arrester current and energy for one restrike on a grounded wye capacitor bank. Note that several calculations may be required to determine the correct voltage (V) for the calculated arrester current (I_A).

$$I_A = \frac{\sqrt{2.6(E)^2 - (B)^2}\,\sqrt{I_F C}}{39\sqrt{E}}$$

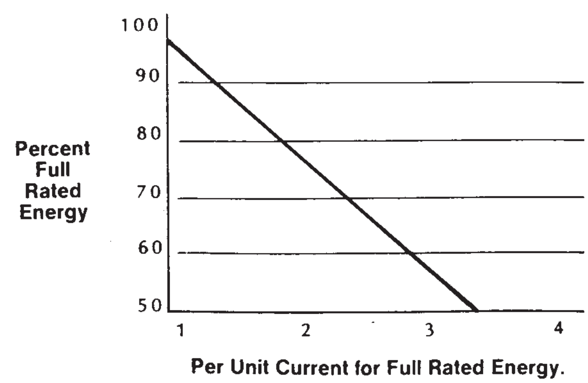
$$\text{Energy (kJ)} = \frac{0.8\,EV\,(I_A)^2}{BI_F}$$

Where I_A = Arrester current, kA
E = System line-line nominal voltage, kV
B = V - 0.82E
V = Arrester switching surge discharge voltage at I_A, kV
I_F = Available system fault current at arrester location, kA
C = Single phase capacitor bank or cable capacitance, μF.
For shunt capacitor banks,
$C = \frac{2650 \bullet \text{MVAR}}{E^2}$ where MVAR is 3-phase.

FIGURE 9

This calculation should be conservative for cables because of the cable's higher impedance. If more than a single restrike can occur, maximum energy is difficult to calculate, and a computer model study should be performed.

For example, the calculation for one restrike for a 230 kV shunt capacitor bank of 75 MVAR, using a VS-140 arrester with a V of 350 kV, and assuming available fault current of 10 kA, yields an arrester current of 3.5 kA and energy of 490 kJ. Since the current exceeds the full energy current for a VS of 1.5 kA, Figure 9A must be used to find the energy capability. Current of 3.5 kA is 2.33 per unit of full rated current, so the energy capability must be de-rated to 70 percent of 8.9, or 6.2 kJ/kV. Energy of 490 kJ is only 3.5 kJ/kV, so this is a safe application.



Full current is as follows:

VX	2700 AMP for	16.2 kJ/kV MCOV
VS, VN	1500 AMP for	8.9 kJ/kV MCOV
VL, VLA	1000 AMP for	4.9 kJ/kV MCOV
VI, VIA	650 AMP for	3.4 kJ/kV MCOV

FIGURE 9 A

Temporary Dynamic Overvoltages

These voltages are not uncommon, occurring to a modest degree when there is a ground fault. However, those of sufficient magnitude to cause concern for arrester damage require unusual system conditions. The receiving end of a very long unloaded and uncompensated EHV line, perhaps with an unloaded transformer, is one example. Another is an isolated section of high-voltage line backfed through a relatively small transformer.

In DynaVar intermediate and station Type VL, VLA and VN gapless arresters, all voltages appear on the valve element. These arresters can withstand 111 percent of MCOV for periods of 2000 hours (See Figure 10).

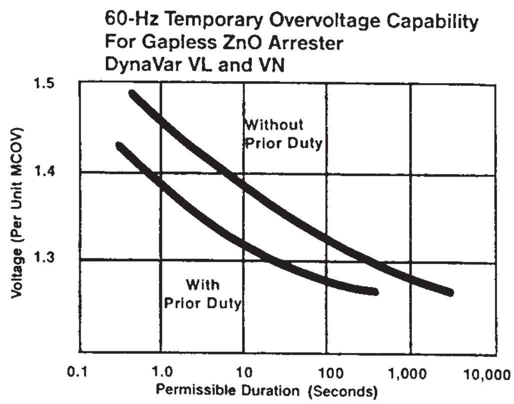


FIGURE 10

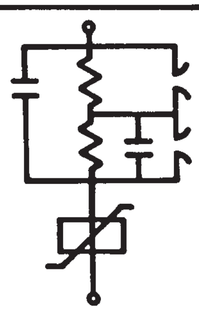


FIGURE 11
Schematic of DynaVar VS arresters.

For DynaVar station class arresters, Types VS and VX, the gapped series impedance reduces the voltage on the valve element and improves dynamic overvoltage withstand (Figure 11). When voltage rises above the maximum continuous level, or when arrester temperature is increased substantially, the metal-oxide valve element resistance decreases, which shifts a greater portion than normal of the voltage to the series impedance, and thereby limits the watts loss in the valve element (Figure 12).

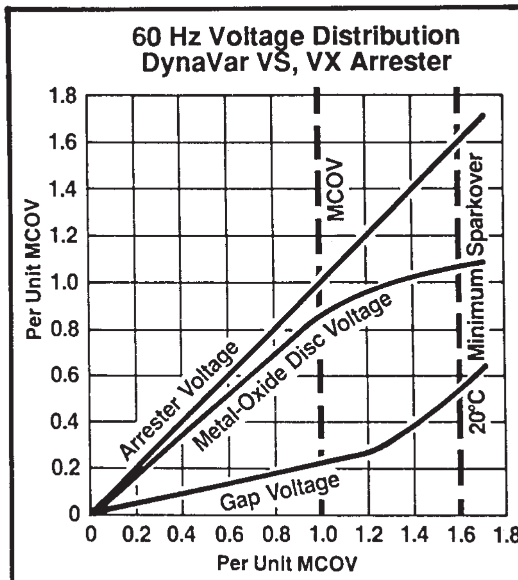


FIGURE 12

Plot of valve element voltage compared to total arrester voltage.

Figure 13 shows how an increase in temperature causes only a modest increase in arrester current and watts loss since some voltage shifts to the series impedance.

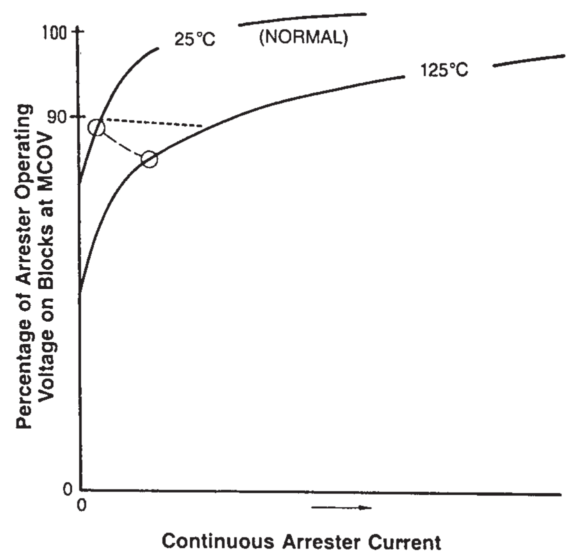


FIGURE 13
Proportion of voltage on valve element decreases as arrester temperature increases, limiting loss and promoting rapid cooling to normal temperature.

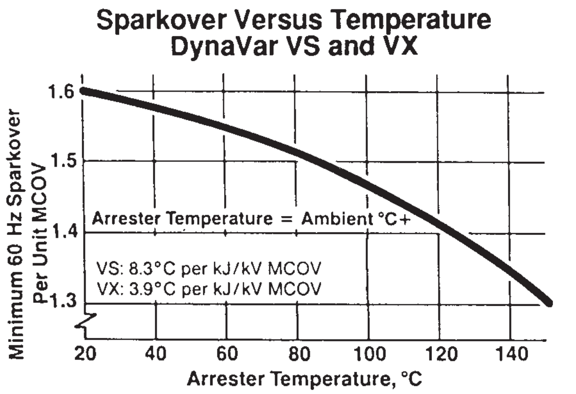


FIGURE 14

If dynamic overvoltages do not exceed the sparkover of the gap shunting the series impedance, they are no major concern. Figure 14 shows minimum power frequency sparkover as a function of arrester temperature. The arrester will withstand any voltage below the curves for a time greatly exceeding the system disturbance which causes the overvoltage. Figure 15 illustrates the overvoltage capability with and without prior duty for DynaVar VS and VX.

The curves show the gap will spark over on few temporary overvoltages at reasonable temperatures. For example, at 60°C (140°F) DynaVar gapped arresters can withstand over 1.5 p.u. without sparkover.

Arrester temperature is determined by weather plus immediately preceding surge duty. The arrester temperature can rise 8.3°C for each kJ/kV MCOV of internally dissipated energy for VS arresters of 42 kV to 245 kV, and 3.9°C per kJ/kV MCOV for VX arresters of 318 kV to 485 kV. Therefore, the transient rise caused by surges of maximum repeatable severity is 8.3°C/kJ × 8.9kJ = 74°C for 42 kV to 245 kV arresters and 3.9°C/kJ × 16.2 kJ = 63°C for 318 kV to 485 kV arresters (see Table III).

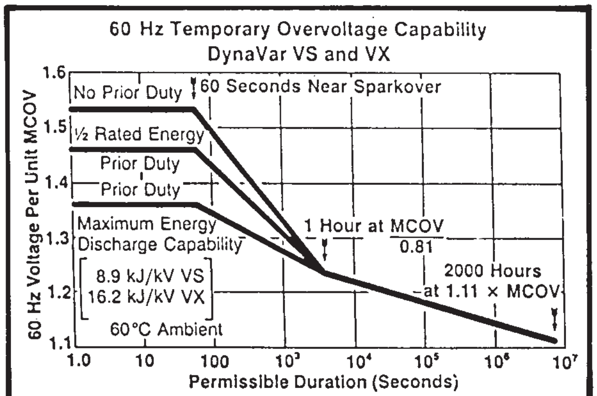


FIGURE 15

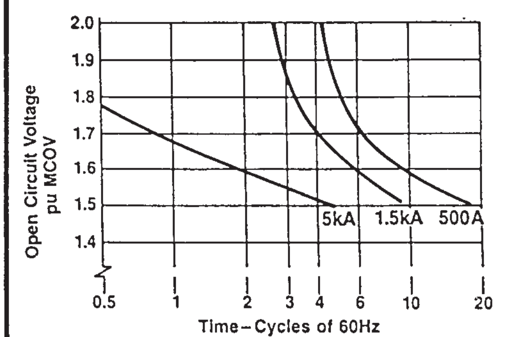


FIGURE 16

Type VS arrester, MCOV 42 to 245 kV. Temporary dynamic overvoltage capability if gap is sparked over every half-cycle. The currents identifying the curves are the prospective system fault currents at the arrester location during the overvoltage.

This information makes it possible to use Figure 14 in more detail. For example, assume the following conditions:

- 100-mile section 362 kV line
- 209 kV MCOV DynaVar arrester
- Arrester temperature (from ambient conditions) 100°F (38°C)
- Reclosing on ground fault causes 2.7 p.u. surge unfaulted phase followed by a few cycles of 1.3 p.u. dynamic overvoltage.

Will the arrester continue to spark over after the switching surge?

Figure 3 shows that 400 miles of single 362 kV line charge to 2.7 p.u. are required to equal the surge capability of the arrester (causing a 74°C transient temperature rise). The 100-mile line will cause approximately one-fourth this rise.

The arrester temperature after the switching surge is thus 38°C + 74°C/4 = 57°C. Arrester minimum sparkover, from Figure 14, is just over 1.55 p.u., so the gap will not continue to spark over after the reclosing surge.

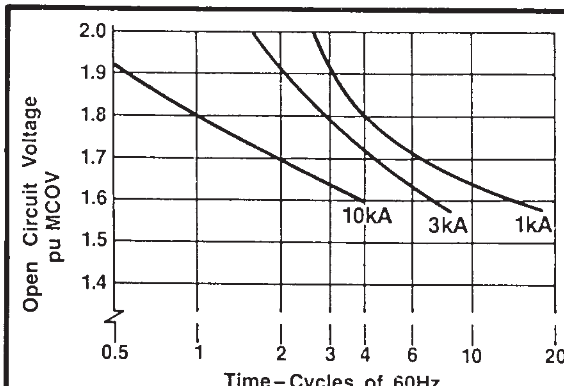


FIGURE 17

Type VX arrester, MCOV 318 to 485 kV. Temporary dynamic overvoltage capability if gap is sparked over every half-cycle. The currents identifying the curves are the prospective system fault currents at the arrester location during the overvoltage.

Above sparkover, the allowable overvoltage duration depends upon how quickly the arrester energy capability is reached and this is difficult to determine. There is frequently a high harmonic content to the voltage, and system fault current at any location where high dynamic overvoltage is occurring is usually low. A detailed computer study can give reasonable accuracy, provided the arrester valve element is modeled with sufficient sophistication regarding time and temperature effects.

Figures 16 and 17 show allowable durations for three different fault current circuits when the open circuit overvoltage is sinusoidal. The withstand times are conservative for voltages of high harmonic content.

The fault currents are the prospective fault currents at the arrester location during the overvoltage. This is usually a small fraction of normal fault current and actual arrester current is much less. The fault current range of 500 A to 5 kA (1 kA to 10 kA for EHV circuits) covers most situations which result in these very high temporary overvoltages.

Example:

What is the three cycle overvoltage capability withstand on a 550 kV system with 3 kA available fault current during the disturbance? Also, what 60 Hz voltage can the arrester withstand immediately after the three-cycle overvoltage without further sparkover, assuming an initial temperature of 140°F (60°C)?

Using Figure 17, since arrester MCOV is assumed 318 kV, the arrester can withstand 1.78 p.u. temporary overvoltage for three cycles. Arrester temperature will then be 60°C + 63°C (maximum energy temperature rise for EHV arresters) = 123°C. Thus, the 60 Hz voltage can be as high as 1.41 p.u. afterward (from Figure 14) without further sparkover.

Insulation Coordination

Table I and Table II show normally recommended DynaVar arrester applications for various system voltages and grounding practice.

Table IV lists protective characteristics for intermediate and station DynaVar arresters. These are discharge voltage characteristics, since arrester sparkover does not affect protective levels.

The switching surge discharge voltage is based on a surge of 45 microseconds time to crest and is measured at classifying currents based on maximum system voltages. These classifying currents are presented in ANSI C62.11 as 500 amperes for maximum system voltage of 150 kV, 1000 amperes for system voltages of 151-325 kV, and 2000 amperes for system voltages of 326-900 kV. The arrester switching surge protective levels and their associated classifying currents are included in Table IV.

The protective characteristics are presented differently in Figures 18 and 19. Note the crest times apply to the discharge voltage -- not current. Typically, discharge voltage crest time is approximately 0.6 x actual crest time of the current. Thus, the 6-microsecond values of Figures 18 and 19 result from 10/20 microseconds (actual) current surges -- 8/20 microseconds by ANSI definition.

For example, from Figure 18, at 6 microseconds, 10-kA discharge voltage is 2.0 p.u. crest MCOV. For a DynaVar VS-140, 140 x 2.0 x 2 = 395. For current waves cresting faster than 10 microseconds, the discharge voltage will be somewhat higher.

Table IV values for various discharge voltages are the maximum protective levels of all DynaVar arresters, because gap sparkover is controlled to be less than the discharge voltage.

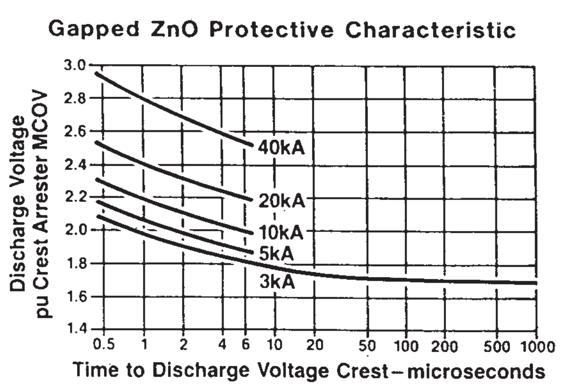


FIGURE 18

Volt-time protective characteristic for VS arresters, 42- to 245 kV. MCOV.

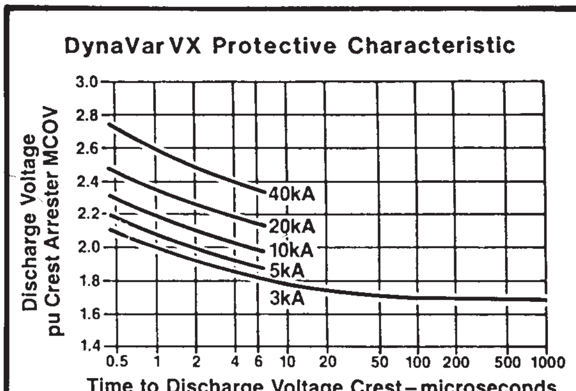


FIGURE 19

Volt-time protective characteristic for VX arresters, 318 to 485 kV. MCOV.

TABLE IV
Protective Characteristics
DynaVar Metal-Oxide Surge Arresters

Type	Standard Arrester Catalog Number	Duty Cycle Rating kV rms	Arrester MCOV-kV rms	Maximum 0.5μs Discharge Voltage kV (1)	Maximum Switching Surge Protective Level At Classifying Current Levels kV (2)		Maximum Discharge Voltage Using an 8/20 Current Wave-kV						
					500A	1000A	1.5kA	3kA	5kA	10kA	15kA	20kA	40kA
VLA	**217003**	3	2.55	9.1	6.3		6.9	7.2	7.5	8	8.6	9	10.3
VLA	**217005**	6	5.1	17.9	12.4		13.6	14.2	14.8	15.8	16.9	17.7	20.3
VLA	**217008**	9	7.65	26.6	18.4		20.2	21.1	22	23.5	25.1	26.4	30.2
VLA	**217009**	10	8.4	29.3	20.3		22.2	23.3	24.2	25.9	27.7	29.1	33.3
VLA	**218510***	12	10.2	35.5	24.6		26.9	28.2	29.4	31.4	33.5	35.2	40.4
VLA	**217013**	15	12.7	44.2	30.6		33.5	35.1	36.6	39.1	41.8	43.9	50.3
VLA	**217015**	18	15.3	53.3	36.8		40.4	42.3	44.1	47.1	50.3	52.8	60.6
VLA	**218517***	21	17	59.1	40.9		44.8	46.9	48.9	52.3	55.8	58.7	67.2
VLA	**218519***	24	19.5	67.8	46.9		51.4	53.8	56.1	60	64.1	67.3	77.1
VLA	**217022**	27	22	76.5	52.9		58	60.8	63.3	67.7	72.3	75.9	87
VL	**216003**	3	2.55	9.1	6.3		6.9	7.2	7.5	8	8.6	9	10.3
VL	**216005**	6	5.1	17.9	12.4		13.6	14.2	14.8	15.8	16.9	17.7	20.3
VL	**219508***	9	7.65	26.6	18.4		20.2	21.1	22	23.5	25.1	26.4	30.2
VL	**219509***	10	8.4	29.3	20.3		22.2	23.3	24.2	25.9	27.7	29.1	33.3
VL	**219510***	12	10.2	35.5	24.6		26.9	28.2	29.4	31.4	33.5	35.2	40.4
VL	**219513***	15	12.7	44.2	30.6		33.5	35.1	36.6	39.1	41.8	43.9	50.3
VL	**216015**	18	15.3	53.3	36.8		40.4	42.3	44.1	47.1	50.3	52.8	60.6
VL	**219517***	21	17	59.1	40.9		44.8	46.9	48.9	52.3	55.8	58.7	67.2
VL	**219519***	24	19.5	67.8	46.9		51.4	53.8	56.1	60	64.1	67.3	77.1
VL	**216022**	27	22	76.5	52.9		58	60.8	63.3	67.7	72.3	75.9	87
VL	**216024**	30	24.4	84.9	58.7		64.3	67.4	70.3	75.1	80.2	84.2	96.5
VL	**219529***	36	29	101	69.7		76.4	80	83.4	89.2	95.2	100	115
VL	**216031**	39	31.5	110	75.8		83	86.9	90.6	96.9	104	109	125
VL	**219536***	45	36.5	128	88.3		96.8	102	106	113	121	127	146
VL	**219539***	48	39	136	93.8		103	108	113	120	128	135	155
VN	**219542**	54	42	135	98		105	112	115	122	130	136	151
VN	**219548**	60	48	154	110		120	127	131	139	149	155	173
VN	**219557**	72	57	183	131		142	151	156	165	177	184	205
VN	**219570**	90	70	223	161		174	184	190	202	216	226	251
VN	**219574**	90	74	236	169		185	195	202	214	229	237	266
VN	**219576**	96	76	242	175		190	201	208	220	235	245	274
VN	**219584**	108	84	267	193		209	221	229	243	260	271	301
VN	**219588**	108	88	279	202		219	232	239	254	272	284	316
VN	**217598***	120	98	311		231	244	257	266	283	303	315	351
VN	**219606**	132	106	340		249	264	280	289	306	327	342	381
VN	**219615**	144	115	368		271	287	303	314	332	355	369	413
VN	**219631**	168	131	418		308	326	345	357	379	406	421	470
VN	**217740***	172	140	446		330	348	368	381	404	432	448	502
VN	**217744***	180	144	458		339	359	380	392	417	446	463	517
VN	**217752***	192	152	483		360	379	401	414	440	471	488	546
VN	**217780***	228	180	571		424	447	474	489	520	556	578	645
VN	**217909***	258	209	665		† 516	522	552	571	604	646	670	752
VN	**217912***	264	212	675		† 523	527	558	576	613	656	680	760
VN	**217920***	276	220	700		† 545	547	578	597	635	679	705	788
VN	**217945***	312	245	778		† 605	609	644	666	708	758	788	878

* Denotes change from previous catalog issue.

TABLE IV (continued)

Type	Standard Arrester Catalog Number	Duty Cycle Rating kV rms	Arrester MCOV-kV rms	Maximum 0.5μs Discharge Voltage kV (1)	Maximum Switching Surge Protective Level At Classifying Current Levels kV (2)		Maximum Discharge Voltage Using an 8/20 Current Wave-kV						
					500A	1000A	1.5kA	3kA	5kA	10kA	15kA	20kA	40kA
VS	**216042**	54	42	132	102		101	106	110	117	125	129	146
VS	**216048**	60	48	153	118		117	123	128	136	146	150	170
VS	**216052**	65	52	163	126		125	131	136	145	155	160	181
VS	**216057**	72	57	180	140		138	145	151	162	173	177	202
VS	**216070**	90	70	221	169		168	176	182	195	209	215	243
VS	**216074**	90	74	231	177		175	184	192	204	218	225	254
VS	**216076**	96	76	240	185		183	191	199	213	228	235	265
VS	**216084**	108	84	265	203		201	211	219	234	250	257	291
VS	**216088**	108	88	278	213		211	220	229	245	262	268	305
VS	**216098**	120	98	309		236	234	245	254	272	291	300	339
VS	**216106**	132	106	334		256	254	266	277	296	317	327	368
VS	**216115**	144	115	362		278	276	289	300	321	343	353	400
VS	**216131**	168	131	414		317	314	329	342	365	391	400	454
VS	**216140**	172	140	441		338	335	350	364	390	417	429	485
VS	**216144**	180	144	454		351	346	363	378	403	431	449	504
VS	**216152**	192	152	480		370	365	383	400	425	455	479	530
VS	**216180**	228	180	568		435	432	452	469	502	537	552	626
VS	**216209**	258	209	660	† 508		503	527	547	585	626	643	730
VS	**216212**	264	212	670	† 516		508	534	557	593	635	655	740
VS	**216220**	276	220	695	† 535		527	554	578	615	658	680	769
VS	**216245**	312	245	778	† 598		590	620	646	688	736	761	860
VX	**216318(3)**	396	318	1070	† 774		776	812	843	890	915	947	1046
VX	**216335(3)**	420	335	1126	† 813		817	855	886	936	965	998	1102
VX	**216470(3)**	588	470	1624	†1140		1148	1201	1245	1313	1360	1404	1547
VX	**216485(3)**	612	485	1676	†1176		1185	1239	1284	1355	1405	1450	1600

† At Classifying Current Level 2000A

(1) Maximum discharge voltage for an impulse current wave which produces a voltage wave cresting in 0.5 μs. Discharge currents are 10 kA for 2.55-245 kV MCOV, 15 kA for 318-355 kV MCOV, and 20 kA for 470-485 kV MCOV. This can be used for coordination where front-of-wave sparkover formerly was used.
(2) Discharge voltages are based on a surge of 45 μs time to crest.
(3) EHV design, double column of valve elements.

Parallel Operation of Different Arrester Designs

Substation design practices, and future additions to existing substations, may cause arresters made by different manufacturers, or of different designs from the same manufacturer, to be connected electrically in parallel on the same phase.

Factors to consider when evaluating this type of construction include, but are not limited to, the distance in circuit-feet between the parallel arresters, the distance from the arresters to protected apparatus, knowledge of which arrester will be the first encountered by a traveling wave entering a station, and the protective level afforded by each arrester design.

Of great significance is the type of traveling wave entering the station, whether a steep front resulting from lightning, or a slow front resulting from a switching surge.

Consider the case where a gapless station arrester is used for a station entrance application and gapless station arrester is located on a transformer, 500 circuit-feet away. If both arresters are the same design and protective level, the station entrance arrester will likely discharge most of any lightning transient energy having a steep wave. However, since the travel time between these arresters is less than a microsecond, they will likely share in any switching surge duty having a slow front.

Consider the case of the above example where the station entrance arrester has a voltage rating or protective level five percent higher than the arrester on the transformer. In this example, the station entrance arrester will still discharge most of the lightning energy, but most of the switching surge energy will be dissipated by the smaller arrester located at the transformer. Again, the travel time between arresters has determined the duty of each arrester.

Consider the case where the station entrance arrester is a gapped silicon carbide design and the arrester on the transformer is a gapless MOV design. Due to the steep front of an incoming lightning transient wave, the gapped silicon carbide arrester will probably absorb most of the lightning surge energy. However, the arrester at the transformer will likely absorb most of the switching surge energy since it will conduct significant current before the gap sparks over in the silicon carbide arrester. And in some applications, the protective level of the MOV arrester located at the transformer will protect the station entrance arrester so the gap will not spark over.

Consider the case of a gapped silicon carbide arrester on the transformer and a new MOV arrester installed elsewhere on the bus, such as at the station entrance. In this case, the MOV arrester will likely absorb most of the lightning and switching surge energy. The arrester at the transformer may operate only after the incoming transient is reflected by the high impedance of the transformer and if reflection causes sparkover of the gap in the silicon carbide design.

Other Considerations

Ambient temperature: DynaVar arresters are designed to be used at temperatures not exceeding 60°C (140°F) and where average daily temperature does not exceed 40°C (104°F). Types VS and VX station class arresters are made less sensitive to high ambient temperature by the linear series impedance (Figure 13). Higher than normal temperature will affect overvoltage performance, as previously explained, and should be considered in assessing such duty.

Contamination: The highly nonlinear characteristics of the metal-oxide valve element in DynaVar arresters give them outstanding ability to resist the effects of external porcelain contamination. Since the series impedance in Types VS and VX arresters carries only about 20 percent of the total arrester voltage during normal operation, momentary sparkover of all the gaps in a DynaVar arrester from contamination effects at normal operating voltage, though extremely unlikely, would not cause damage to the arrester.

In highly contaminated locations where insulation flashover may be a problem, the creepage distance of the DynaVar arrester should be at least as great as other station insulation. DynaVar arresters can be installed in special housings to obtain extra creep.

Hot washing of DynaVar arresters using normal precautions is permissible.

Pressure Relief

All DynaVar intermediate and station class surge arresters exceed pressure relief requirements of ANSI C62.11. Following are typical results of high-current pressure relief tests.

UNIT MCOV kV	FAULT CURRENT - kA			DURATION (CYCLES)
	SYM.	ASYM.	PEAK	
VI-33	37.5	54.0	91.9	13.5
VL-33	67.6	104.3	175.0	12.5
VS, VN-84	147.8	140.8	242.9	6.0
VX-136	76.8	79.5	129.3	6.0

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