

S&C Bankgard Relays are solid-state electronic devices which provide low-cost protection for small- to medium-sized station-type, wye-connected shunt capacitor banks having up through five series groups of capacitor units per phase.

The S&C Bankgard Relay—Type LUC is designed for *ungrounded* capacitor-bank applications. It detects neutral-to-ground voltage increments caused by isolation of faulted capacitor units from the bank by their respective fuses. When a predetermined neutral-to-ground voltage is exceeded, the Type LUC Bankgard Relay signals a switching device to disconnect the entire bank, thus protecting the surviving capacitor units in the bank against cascading voltage overstress.

The Type LUC Bankgard Relay does not provide system-voltage or capacitor-bank unbalance compensation. It is therefore applicable only to the sizes and configurations of capacitor banks for which the loss of a single capacitor unit results in a neutral-to-ground voltage increment that is at least twice the maximum expected error voltage. (A certain amount of error voltage is always present between the energized capacitor-bank neutral and ground, due to system-voltage unbalance and to inherent capacitor-bank unbalance resulting from manufacturing-tolerance variations among capacitor units in the bank.)

The S&C Bankgard Relay—Type LGC is designed for *grounded* capacitor-bank applications. It detects neutral-current increments caused by isolation of faulted capacitor units from the bank by their respective fuses. When a predetermined neutral current is exceeded, the Type LGC Bankgard Relay signals a switching device to disconnect the entire bank, thus protecting the surviving capacitor units in the bank against cascading voltage overstress.

The Type LGC Bankgard Relay does not provide system-voltage or capacitor-bank unbalance compensation. It is therefore applicable only to the sizes and configurations of capacitor banks for which the loss of a single capacitor unit results in a neutral-current increment that is at least twice the maximum expected error current. (A certain amount of error current is always present between the energized capacitor-bank neutral and ground, due to system-voltage unbalance and to inherent capacitor-bank unbalance resulting from manufacturing-tolerance variations among capacitor units in the bank.)

The tables on pages 2 and 3 show the capacitor-bank configurations and maximum sizes for which Type LUC and Type LGC Bankgard Relays are suitable, respectively, based on the maximum expected level of total percent unbalance (i.e., the total of percent system-voltage unbalance plus percent inherent capacitor-bank unbalance). Percent system-voltage unbalance is defined as the phasor sum of the three line-to-ground voltages, expressed in percent of the line-to-ground voltage. Percent capacitor-bank unbalance is defined as the maximum difference in capacitance between phases, expressed in percent of the nominal capacitance per phase. Typically, total unbalance will not exceed 3% at distribution substations, or 2% at transmission substations. With careful balancing of capacitor-bank phase legs (by a suitable interchange of individual capacitor units) in transmission-substation applications, it may be possible to reduce total unbalance to 1.5% or 1% maximum.

For larger bank sizes, or for applications where system-voltage unbalance may be greater than normal due to the presence of single-phase regulators or significant individual single-phase loads, S&C Automatic Control Devices—Type UP (for ungrounded banks) or Types GP or GPS (for grounded banks) are recommended, since they can be equipped with unbalance-compensation and alarm options. Refer to the nearest S&C Sales Office.

No intrinsic minimum capacitor-bank size restriction applies to Type LUC or Type LGC Bankgard Relays. The minimum and maximum size listings in the tables on pages 2 and 3 are derived as follows:

- (a) The *minimum* number of capacitor units in parallel per series group—and therefore the minimum number of capacitor units in the bank—is based on the recommendation in IEEE Standard 18-1980 that continuous voltage applied to surviving capacitor units be limited to 110% of rated voltage when one capacitor unit in the group has been isolated. (The capacitor bank may consist of a smaller number of capacitor units in parallel per series group, provided the Bankgard relay is set to initiate isolation of the capacitor bank upon loss of the *first* capacitor unit. Refer to the nearest S&C Sales Office.)
- (b) In the case of the Type LUC Bankgard Relay, the *maximum* number of capacitor units per phase in a series



group—and therefore the maximum number of capacitor units in the bank—is determined by the magnitude of the neutral-to-ground voltage increment caused by isolation of each capacitor unit from the same series group. This voltage increment must be equal to (or greater than) twice the maximum expected error voltage.

In the case of the Type LGC Bankgard Relay, the *maximum* number of capacitor units per phase in a series group—and therefore the maximum number of capacitor units in the bank—is determined by the magnitude of the neutral-current increment caused by isolation of each capacitor unit from the same series group. This current increment must be equal to (or greater than) twice the maximum expected error current.

Although the Bankgard relays themselves are suitable for use with the capacitor-bank sizes shown in the tables, another consideration governs the maximum number of

capacitor units which may be placed in parallel. When a capacitor units fails, the other capacitor units in the same series group will probably contain some amount of charge. This charge will drain off as high-frequency transient current through the faulted unit and its fuse. The fuse holder and the faulted capacitor unit must withstand this discharge transient. Accordingly, the total energy stored in a parallel-connected group of capacitors should not exceed 10,000 watt-seconds at the maximum peak voltage (rated voltage $\times 1.1 \sqrt{2}$). For 60-hertz applications, 3100 kVAC at rated voltage is recommended as the maximum limit for parallel-connected kVAC.

If a bank having the minimum number of series groups requires more than 3100 kVAC per group, selection of capacitor units of a lower voltage rating requiring more series groups and fewer units per group, may be a suitable solution. Another possibility, but a costly one, is the use of current-limiting fuses for the individual capacitor units.

TABLE I —TYPE LUC BANKGARD RELAY APPLICATION—*Ungrounded Wye-Connected Capacitor-Bank Configurations and Sizes*

Maximum Expected Total Percent Unbalance①	Number of Series Groups per Phase	Number of Capacitor Units in Parallel per Group		Total Number of Capacitor Units in Bank		Corresponding Capacitor-Bank Size, kVAC									
		Min. ②	Max	Min.	Max	50-kVAC Units		100-kVAC Units		150-kVAC Units		200-kVAC Units		300-kVAC Units	
						Min.	Max	Min.	Max	Min.	Max	Min.	Max	Min.	Max
5	1	4	10	12	30	600	1500	1200	3000	1800	4500	2400	6000	3600	9000
4	1	4	13	12	39	600	1950	1200	3900	1800	5850	2400	7800	3600	11700▲
3	1	4	17	12	51	600	2550	1200	5100	1800	7650	2400	10200▲	3600	15300▲
	2	8	9	48	54	2400	2700	4800	5400	7200	8100	9600	10800	14400	16200
2.5	1	4	20	12	60	600	3000	1200	6000	1800	9000	2400	12000▲	3600	18000▲
	2	8	11	48	88	2400	3300	4800	6600	7200	9900	9600	13200	14400	19800▲
2	1	4	25	12	75	600	3750	1200	7500	1800	11250▲	2400	15000▲	3600	22500▲
	2	8	13	48	78	2400	3900	4800	7800	7200	11700	9600	15600	14400	23400▲
1.5■	1	4	34	12	102	600	5100	1200	10200▲	1800	15300▲	2400	20400▲	3600	30600▲
	2	8	17	48	102	2400	5100	4800	10200	7200	15300	9600	20400▲	14400	30600▲
	3	9	12	81	108	4050	5400	8100	10800	12150	16200	16200	21600	24300	32400▲
	4	9	9	108	108	5400	5400	10800	10800	16200	16200	21600	21600	32400	32400
1■	1	4	50	12	150	600	7500	1200	15000▲	1800	22500▲	2400	30000▲	3600	45000▲
	2	8	25	48	150	2400	7500	4800	15000	7200	22500▲	9600	30000▲	14400	45000▲
	3	9	17	81	153	4050	7650	8100	15300	12150	22950	16200	30600▲	24300	45900▲
	4	9	13	108	156	5400	7800	10800	15600	16200	23400	21600	31200	32400	46800▲
	5	10	11	150	165	7500	8250	15000	16500	22500	24750	30000	33000	45000	49500▲

① Total of system-voltage unbalance plus capacitor-bank unbalance due to manufacturing-tolerance variations, as defined on page 1.

② Minimum number of capacitor units in parallel per series group is based on the recommendation in IEEE Standard 18-1980 that continuous voltage applied to surviving capacitor units be limited to 110% of rated voltage when one capacitor unit in the group has been isolated. (The capacitor bank may consist of a smaller number of capacitor units in parallel per series group, provided the Bankgard relay is set to initiate isolation of the capacitor bank upon loss of the *first* capacitor unit. Refer to the nearest S&C Sales Office.)

■ May be possible with careful balancing of capacitor-bank phase legs by a suitable interchange of individual capacitor units, assuming system-voltage unbalance is negligible.

▲ Total energy of parallel-connected groups exceeds 10,000 watt-seconds. Use capacitor units of a lower voltage rating arranged in a larger number of series groups, or use current-limiting fuses for the individual capacitor units.

TABLE I I—TYPE LGC BANKGARD RELAY APPLICATION—*Grounded Wye-Connected Capacitor-Bank Configurations and Sizes*

Maximum Expected Total Percent Unbalance ^①	Number of Series Groups per Phase	Number of Capacitor Units in Parallel per Group		Total Number of Capacitor Units in Bank		Corresponding Capacitor-Bank Size, kVAC									
		Min. ^②	Max	Min.	Max	50-kVAC Units		100-kVAC Units		150-kVAC Units		200-kVAC Units		300-kVAC Units	
						Min.	Max	Min.	Max	Min.	Max	Min.	Max	Min.	Max
4	2	6	7	36	42	1800	2100	3600	4200	5400	6300	7200	8400	10800	12600
3	2	6	9	36	54	1800	2700	3600	5400	5400	8100	7200	10800	10800	16200
2.5	2	6	11	36	66	1800	3300	3600	6600	5400	9900	7200	13200	10800	19800
2	2	6	13	36	78	1800	3900	3600	7800	5400	11700	7200	15600	10800	23400▲
	3	8	9	72	81	3600	4050	7200	8100	10800	12150	14400	16200	21600	24300
1.5■	2	6	17	36	102	1800	5100	3600	10200	5400	15300	7200	20400▲	10800	30600▲
	3	8	12	72	108	3600	5400	7200	10800	10800	16200	14400	21600	21600	32400▲
1■	2	6	25	36	150	1800	7500	3600	15000	5400	22500▲	7200	30000▲	10800	45000▲
	3	8	17	72	153	3600	7650	7200	15300	10800	22950	14400	30600▲	21600	45900▲
	4	9	13	108	156	5400	7800	10800	15600	16200	23400	21600	31200	32400	46800▲
	5	9	11	135	165	6750	8250	13500	16500	20250	24750	27000	33000	40500	49500▲

① Total of system-voltage unbalance plus capacitor-bank unbalance due to manufacturing-tolerance variations, as defined on page 1.

② Minimum number of capacitor units in parallel per series group is based on the recommendation in IEEE Standard 18-1980 that continuous voltage applied to surviving capacitor units be limited to 110% of rated voltage when one capacitor unit in the group has been isolated. (The capacitor bank may consist of a smaller number of capacitor units in parallel per series group, provided the Bankgard relay is set to initiate isolation of the capacitor bank upon loss of the *first* capacitor unit. Refer to the nearest S&C Sales Office.)

■ May be possible with careful balancing of capacitor-bank phase legs by a suitable interchange of individual capacitor units, assuming system-voltage unbalance is negligible.

▲ Total energy of parallel-connected groups exceeds 10,000 watt-seconds. Use capacitor units of a lower voltage rating arranged in a larger number of series groups, or use current-limiting fuses for the individual capacitor units.

