Section 3
Circuit Breaker Selection

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INTRODUCTION

A circuit breaker’s function and intended use are established in ANSI-C37.100-1992, Definitions for Power Switchgear, which defines a circuit breaker as:

“A mechanical switching device, capable of making, carrying, and breaking currents under normal circuit conditions and also, making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit.”

In addition, it is noted that a circuit breaker is intended usually to operate infrequently, although some types are suitable for frequent operation.

A circuit breaker is applied generally to carry and switch load current and to interrupt short-circuit current when required. The application process is simple: each of the duty requirements is specified or calculated and is then compared to the corresponding capability of the circuit breaker. The fundamental rule for selection of the proper circuit breaker is that the ratings or related capabilities of the circuit breaker must equal or exceed each of the calculated or specified duty requirements of the circuit in which it is applied.

CIRCUIT BREAKER RATINGS

Power/Vac circuit breaker ratings with K=1 are shown in Table 3-1.1. Table 3-1.2 lists Power/Vac circuit breakers with ratings based on the previous revision of ANSI C37.06 (1987), with K factors greater than 1.0. Interrupting ratings are for 60-HZ and 50-HZ applications. For more complete information concerning service conditions, definitions, interpretation of ratings, tests, and qualifying terms, refer to the applicable ANSI and NEMA standards listed in Table 1-1, Page 1-3.

SELECTION CONSIDERATIONS

Application of the proper circuit breaker requires a definition of its duty requirements, which can then be compared with the choice of a Power/Vac circuit breaker with ratings and capabilities shown in Table 3-1.1 or 3-1.2. It is recommended that ANSI Standard C37.010 (see Ref.2 of this section) be consulted for guidance in proper determination of duty requirements. Circuit characteristics which must be considered are discussed in the following paragraphs. Circuit characteristics which must be defined and compared to the circuit breaker’s capabilities (given in the various Tables in this Section) are:

- Circuit voltage
- System frequency
- Continuous current
- Short-circuit current
- Closing and latching current

In addition, certain special application conditions can influence circuit breaker selection. Special applications include the following:

- Repetitive switching duty (except arc furnaces)
- Arc furnace switching
- Reactor switching
- Capacitor switching
- Fast bus transfer
- Unusual service conditions

This section of the Power/Vac Application Guide provides specific parameters and guidelines for circuit breaker selection and application. Specifically, those circuit parameters and special applications noted in the proceeding paragraph are addressed.

CIRCUIT VOLTAGE

The nominal voltage classes of medium-voltage metalclad switchgear based on ANSI standards are 4.16 kV, 7.2 kV and 13.8 kV. Power/Vac switchgear may be applied at operating voltages from 2400 volts through 15,000 volts, provided the maximum circuit operating voltage does not exceed the Power/Vac rated maximum voltage, see Table 3-1.1 or Table 3-1.2.
<table>
<thead>
<tr>
<th>Rated Maximum rms Voltage (kV)</th>
<th>Nominal ANSI Voltage Class (kV)</th>
<th>Typical System Operating Voltages (kV)</th>
<th>Rated Voltage Range Factor, K</th>
<th>Rated Withstand Test Voltage</th>
<th>Continuous rms Current Rating at 60Hz (amperes)</th>
<th>Rated Short Circuit Current (Maximum Interrupting Capability) (kA)</th>
<th>Rated Interrupting Time (Cycles)</th>
<th>Rated Permissible Tripping Delay, Y (Seconds)</th>
<th>2 Sec Short time Current Carrying Capability (kA)</th>
<th>Peak Close and Latch (2.6K x short circuit current rating) (kA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.76</td>
<td>4.16</td>
<td>2400</td>
<td>1.0</td>
<td>19</td>
<td>60</td>
<td>1200-4000</td>
<td>40</td>
<td>5 or 3</td>
<td>31.5</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4160</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>50</td>
<td>5 or 3</td>
<td>40</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4200</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>63 *</td>
<td>5</td>
<td>63</td>
<td>164</td>
</tr>
<tr>
<td>8.25</td>
<td>7.2</td>
<td>6600</td>
<td>1.0</td>
<td>36</td>
<td>95</td>
<td>1200-4000</td>
<td>40</td>
<td>5 or 3</td>
<td>40</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6900</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>50 *</td>
<td>5 or 3</td>
<td>50</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7200</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>63 *</td>
<td>5</td>
<td>63</td>
<td>164</td>
</tr>
<tr>
<td>15</td>
<td>13.8</td>
<td>12000</td>
<td>1.0</td>
<td>36</td>
<td>95</td>
<td>1200-4000</td>
<td>20</td>
<td>5 or 3</td>
<td>20</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12470</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>25</td>
<td>5 or 3</td>
<td>25</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13200</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>31.5</td>
<td>5 or 3</td>
<td>31.5</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13800</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>40</td>
<td>5 or 3</td>
<td>40</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14400</td>
<td></td>
<td></td>
<td></td>
<td>1200-4000</td>
<td>50</td>
<td>5 or 3</td>
<td>50</td>
<td>130</td>
</tr>
</tbody>
</table>

Notes:
1. Maximum voltage for which the breaker is designed and upper limit of operation.
2. Available current ratings are 1200A, 2000A, 3000A, 3500A and 4000A. 4000A rating is forced-air cooled, indoor construction only.
   3500A is available in outdoor construction, but must be derated to 3250A.
3. At system operating voltages equal to or less than rated maximum voltage.
   * Ratings offered in addition to the ANSI preferred values.
## Table 3-1.2 Power/Vac® Power Circuit Breaker Characteristics, K>1.0

### Power/Vac® Power Circuit Breaker Characteristics

Symmetrical Ratings Basis ANSI C37.06 (1987)

<table>
<thead>
<tr>
<th>Nominal rms Voltage Class (kV)</th>
<th>Nominal MVA Class (6)</th>
<th>Rated Maximum Voltage rms (kV) (1)</th>
<th>Rated Voltage Range Factor, K (2)</th>
<th>Rated Withstand Test Voltage</th>
<th>Continuous rms Current Rating at 60Hz (amperes) (7) &amp; (8)</th>
<th>Short Circuit rms Current Rating (at Rated Max. kV) (kA) (3) (4)</th>
<th>Rated Interrupting Time (Cycles) (9)</th>
<th>Rated Permissible Tripping Delay, Y (Seconds)</th>
<th>Maximum Symmetrical Interrupting Capability (5)</th>
<th>3 Sec Short time Current Carrying Capability (5)</th>
<th>Closing and Latch Capability rms Current (kA) (10)</th>
<th>Peak Close and Latch (2.7K x max SC rating) (kA) (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.16</td>
<td>250</td>
<td>4.76</td>
<td>1.24</td>
<td>19</td>
<td>1200-4000</td>
<td>29</td>
<td>5</td>
<td>3.85</td>
<td>36</td>
<td>36</td>
<td>58</td>
<td>97</td>
</tr>
<tr>
<td>3.50</td>
<td>500</td>
<td>8.25</td>
<td>1.25</td>
<td>36</td>
<td>1200-4000</td>
<td>33</td>
<td>2</td>
<td>4.0</td>
<td>49</td>
<td>49</td>
<td>78</td>
<td>132</td>
</tr>
<tr>
<td>450 (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.76</td>
<td>63</td>
<td>63</td>
<td>101</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>7.2</td>
<td>500</td>
<td>8.25</td>
<td>1.25</td>
<td>36</td>
<td>1200-4000</td>
<td>33</td>
<td>2</td>
<td>6.6</td>
<td>41</td>
<td>41</td>
<td>66</td>
<td>111</td>
</tr>
<tr>
<td>785 (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.25</td>
<td>63</td>
<td>63</td>
<td>101</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>13.8</td>
<td>500</td>
<td>15</td>
<td>1.30</td>
<td>36</td>
<td>1200-4000</td>
<td>18</td>
<td>11.5</td>
<td>23</td>
<td>23</td>
<td>37</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>750</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.5</td>
<td>36</td>
<td>36</td>
<td>58</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.5</td>
<td>48</td>
<td>48</td>
<td>77</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>1500 (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>63</td>
<td>63</td>
<td>101</td>
<td>164</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1. Maximum voltage for which the breaker is designed and the upper limit for operation.
2. K is the ratio of the maximum voltage to the lower limit of the range of operating voltage in which the required symmetrical and asymmetrical interrupting capabilities vary in inverse proportion to the operating voltage.
3. To obtain the required symmetrical interrupting capability of a circuit breaker at an operating voltage between 1/K times rated maximum voltage and rated maximum voltage, the following formula shall be used:

   \[
   \text{Required Symmetrical Interrupting Capability} = \frac{\text{Rated Short-Circuit Current}}{K} \times \frac{\text{Rated Maximum Voltage}}{\text{Operating Voltage}}
   \]

   For operating voltages below 1/K times rated maximum voltage, the required symmetrical interrupting capability of the circuit breaker shall be equal to K times the rated short-circuit current.
4. With the limitation stated in 5.10 of ANSI-C37.04-1991, all values apply for polyphase and line-to-line faults. For single phase-to-phase faults, the specific conditions stated in 5.10.2.3 of ANSI-C37.04-1991 apply.
5. Current values in this column are not to be exceeded even for operating voltages below 1/K times maximum voltage.
6. MVA Class listed for reference only. Note 4160V-450MVA, 7.2KV-785MVA and 13.8KV-1500MVA are not listed as preferred ratings according to table 2.1 of ANSI-C37.06-1987. For these ratings the Short Time current is on a 2 sec basis, and the peak C&L is 2.6 X S/C rating.
7. Available current ratings are 1200A, 2000A, 3000A, 3500A and 4000A. 3500A and 4000A are indoor construction only.
8. 4000A breaker is forced-air cooled, and indoor construction only.
9. 3 cycle interrupting ratings may be available, consult Factory.
10. Non-standard, high Close & Latch ratings may be available, consult Factory.
SYSTEM FREQUENCY

The frequency rating of Power/Vac metalclad switchgear should coincide with the nominal frequency of the power system. Standard Power/Vac is rated at 60-Hz (Tables 3-1.1 and 3-1.2) per ANSI standards, however can typically be applied at 50-Hz as well. Special frequency applications should be referred to the nearest GE Office.

SHORT-CIRCUIT CURRENT

Quick interruption of short-circuit current is usually considered the primary function of a circuit breaker. The fault-current interrupting capability of Power/Vac circuit breakers is stated in three-phase, symmetrical, rms AC amperes. Accordingly, calculation of the maximum available fault duty of a circuit breaker assumes a three-phase bolted fault.

After calculation of short-circuit current duty, choose a Power/Vac breaker of the proper voltage class and which has a short-circuit current capability that equals or exceeds the expected duty. If applying breakers with K factors > 1.0, remember to consider the circuit operating voltage when evaluating the circuit breaker’s interrupting capability. For example: a 4.16 kV-350 MVA-class circuit breaker has a rated short-circuit current of 41 kA at a maximum rated voltage of 4.76 kV, but has a short-circuit capability of 47 kA symmetrical rms current at 4.16 kV. However when applied on a 2.4 kV system, the interrupting capability increases to 49 kA, which is the maximum symmetrical interrupting capability listed in the rating tables, because 2.4 kV is less than 4.76 kV divided by “k”, or 4.76/1.19 = 4.0 kV. (See footnote No. 5, Table 3-1.2).

CLOSING AND LATCHING CURRENT

Circuit breakers are designed to stay latched, or to close and latch, against a first-cycle maximum asymmetrical rms current which is approximately 1 1/2 times the maximum symmetrical rms interrupting capability of the circuit breaker. This close and latch capability is satisfactory for most applications (Table 3-1.1 and 3-1.2). However there are some applications in which the calculated rms value of first-cycle asymmetrical short-circuit current, exceeds the closing and latching capability of the otherwise suitable circuit breaker. Applications which include large motor loads may generate these higher first-cycle currents. In these cases, breaker selection may depend on closing and latching capability rather than symmetrical short-circuit capability. The breaker selected may have the next higher short-circuit current capability.

For circuit breakers with K factor =1.0, the closing and latching capability (kA, rms) of the circuit breaker is equal to 1.55 K times rated short-circuit current. If close & latch is expressed in peak amperes, the value is equal to 2.6 K times rated short-circuit current.

For circuit breakers with K > 1.0, closing and latching capability (kA, rms) of the circuit breaker is equal to 1.6 K times rated short-circuit current and if expressed in peak amperes, the value is equal to 2.7 K times rated short-circuit current (see ANSI C37.06-2000 for details).

CONTINUOUS CURRENT

Feeder and main breaker loading determines the required continuous current duty. For continuous loads, select a Power/Vac breaker with rated continuous current (defined at 60-Hz) equal to or greater than load current.

Note that Power/Vac circuit breakers are 100% rated, and have no continuous overload rating. When considering circuit breaker applications with a generator, a motor, a transformer, or other apparatus having a long-time overload rating, the circuit breaker (and switchgear equipment) must have a continuous-current rating at least equal to the overload rating of the served apparatus. When applied with a forced-air cooled transformer, the switchgear continuous-current rating must equal or exceed the transformer forced-air cooled current rating.

Circuit breakers may be operated for short periods, in excess of their rated continuous current. This covers such operations as starting motors or energizing cold loads. Consult ANSI C37.20.2 for overload current capability guidelines.

RATED INTERRUPTING TIME

Power/Vac circuit breakers are available with interrupting ratings of 5-cycles or 3-cycles, as stated in Tables 3-1.1 and 3-1.2. For additional information contact your GE Sales Engineer.
Circuit Breaker Selection

DUTY CYCLE

Power/Vac circuit breakers have a rated duty cycle of: O – 0 sec – CO – 15 sec – CO. Power/Vac vacuum breakers do not require derating for reclosing duties.

SPECIAL SWITCHING APPLICATIONS

Application of power circuit breakers for switching duty may require derating of the circuit breaker, or increased maintenance. Power/Vac circuit breakers do not require derating when applied in automatic reclosing duty.

Particular attention should be given to breakers intended for use in any of the following switching applications:
- Repetitive switching (except arc furnace)
- Arc furnace switching
- Reactor switching
- Capacitor switching
- Fast bus transfer

For these applications, the usual practice is to first select a circuit breaker based on the criteria provided under “SELECTION CONSIDERATIONS” of this section. Then consider the switching duty and, if necessary, redetermine the circuit breaker capabilities (continuous-current rating, interrupting rating, etc.), and factor in any modified operating or maintenance requirements. Recheck the circuit breaker’s evaluation capabilities against all the basic duty requirements under “SELECTION CONSIDERATIONS.”

If the circuit breaker selected initially, and as derated (or otherwise modified), no longer meets the duty requirements of the application, choose the next-higher rated breaker. Repeat the derating or rating adjustment process to confirm that the new breaker has adequate capability.

REPEITIVE SWITCHING
(EXCEPT ARC FURNACE)

Power/Vac circuit breakers can be applied on most power circuits without concern to frequency of operation, since highly repetitive switching duty is uncommon. Typical switching duties include motor starting, switching of distribution circuits, transformer magnetizing current, and other miscellaneous load-current switching. While the magnitude of current switched in these applications can vary from very light load to the maximum permissible for a particular circuit breaker, switching is generally infrequent; thus, no derating is required.

Standard Power/Vac circuit breakers may be operated (open-close) as often as 20 times in 10 minutes, or 30 times in one hour without adverse effect. Further frequency of operation capabilities are given in Table 3-2. When operated under usual service conditions and for other than arc furnace switching, standard Power/Vac circuit breakers are capable of operating the number of times shown in the table. Operating conditions, servicing requirements and permissible effects on the breakers are specified in Table 3-2.

ARC FURNACE SWITCHING

Arc furnace switching duty is more repetitive than normal switching duty. The circuit breaker is applied on the primary side of a relatively high-impedance transformer and the usual application requires frequent switching (50 to 100 times per day) of the transformer magnetizing current. Switching is required when the transformer is de-energized for tap changing, when taking melt samples, or when adding alloys. In addition to this switching duty, transformer through-faults must occasionally be interrupted.

This heavy-duty application requires circuit breaker capabilities and maintenance schedules different from those required for other switching duty.

Power/Vac circuit breakers designed for arc furnace switching are capable of operating the number of times given in Table 3-3, providing they are operated under usual service conditions. Operating conditions, servicing requirements, and permissible effects on the breakers are given in the table.

REACTOR SWITCHING

Standard Power/Vac circuit breakers are capable of switching reactive load current up the full continuous current rating of the breaker.

Consult the nearest GE Sales Office for additional information on reactor switching.
### Table 3-2 Repetitive Duty and Normal Maintenance for Power/Vac® Breakers used in Mild Environments other than for Arc Furnace Switching

<table>
<thead>
<tr>
<th>BREAKER KA Rating</th>
<th>CONTINUOUS RATING - AMPS</th>
<th>MAXIMUM NO. OF OPERATIONS BEFORE SERVICING</th>
<th>NUMBER OF OPERATIONS (EACH = 1 CLOSE PLUS 1 OPEN OPERATION)</th>
<th>CONTINUOUS CURRENT SWITCHING</th>
<th>INRUSH-CURRENT SWITCHING</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLUMN 1</td>
<td>COLUMN 2</td>
<td>COLUMN 3</td>
<td>COLUMN 4</td>
<td>COLUMN 5</td>
<td></td>
</tr>
<tr>
<td>A.</td>
<td>Servicing consists of adjusting, cleaning, lubrication, changing parts, as recommended by the Company. The operations listed are on the basis of service in a mild environment.</td>
<td>B.</td>
<td>Close and trip, no-load.</td>
<td>C.</td>
<td>Close and trip within rated current, rated maximum voltage and 80% PF or greater.</td>
</tr>
<tr>
<td>E.</td>
<td>Rated control voltage.</td>
<td>F.</td>
<td>Frequency of operation not more than 20 in 10 minutes or not more than 30 in 1 hour.</td>
<td>G.</td>
<td>Applies</td>
</tr>
<tr>
<td>G.</td>
<td>Servicing at intervals given in Column 2.</td>
<td>I.</td>
<td>Applies</td>
<td>J.</td>
<td>Applies</td>
</tr>
<tr>
<td>H.</td>
<td>No parts replacement.</td>
<td>I.</td>
<td>Applies</td>
<td>J.</td>
<td>Applies</td>
</tr>
<tr>
<td>I.</td>
<td>Breaker meets all current, voltage, interrupting current ratings.</td>
<td>J.</td>
<td>Applies</td>
<td>K.</td>
<td>Applies</td>
</tr>
<tr>
<td>L.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 20-40kA | All | 10,000 or 10 years | 10,000 minimum | 10,000 | 10,000 |
| 50 & 63kA | All | 5,000 or 10 years | 5,000 minimum | 5,000 | 5,000 |

### Table 3-3—Repetitive Duty and Maintenance Requirements for Power/Vac® Circuit Breakers Applied to Arc Furnace Switching

<table>
<thead>
<tr>
<th>BREAKER TYPE</th>
<th>CONTINUOUS RATING (AMPERES)</th>
<th>ARE FURNACE FULL-LOAD RATING (AMPERES)</th>
<th>MAXIMUM NUMBER OF OPERATIONS BETWEEN SERVICING</th>
<th>NO-LOAD MECHANICAL SWITCHING AND INTERRUPTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLUMN 1</td>
<td>COLUMN 2</td>
<td>COLUMN 3</td>
<td>COLUMN 4</td>
<td>COLUMN 5</td>
</tr>
<tr>
<td>A.</td>
<td>Servicing consists of adjusting, cleaning, lubrication, tightening, changing parts, as recommended by the Company. The operations listed are on the basis of service in a mild environment.</td>
<td>B.</td>
<td>When closing and opening no-load.</td>
<td>C.</td>
</tr>
<tr>
<td>D.</td>
<td>Applies</td>
<td>E.</td>
<td>Within 90 to 100% of rated control voltage.</td>
<td>F.</td>
</tr>
<tr>
<td>G.</td>
<td>Frequency of operation not more than 20 in 10 minutes or not more than 30 in 1 hour.</td>
<td>H.</td>
<td>Servicing at no greater interval than shown in Column 4.</td>
<td>I.</td>
</tr>
<tr>
<td>J.</td>
<td>No parts replacement.</td>
<td>K.</td>
<td>Applies</td>
<td>L.</td>
</tr>
<tr>
<td>G.</td>
<td>Breaker meets all current, voltage, interrupting current ratings.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 18-40kA | All | All | 10,000 or 10 years | 10,000 minimum |
| 50 & 63kA | All | All | 5,000 or 10 years | 5,000 minimum |
CAPACITOR SWITCHING

Capacitor banks are generally applied on both utility and industrial power systems to improve voltage regulation and system stability. Power/Vac circuit breakers properly equipped are applicable as General Purpose circuit breakers for shunt-capacitor-bank switching, or as Definite Purpose Circuit Breakers with back-to-back capacitor switching capabilities as listed in Table 3-4.

Shunt-bank capacitor switching means one breaker feeding one 3-phase capacitor bank. If this circuit is closely paralleled by another switched capacitor bank, the duty is considered back-to-back. These situations require evaluation of such factors as local high-frequency equalizing currents flowing between the separated, switched capacitor banks.

### Table 3-4 Power/Vac® Breaker Capacitor Switching Capabilities

<table>
<thead>
<tr>
<th>Breaker Rated Maximum Voltage (kV RMS)</th>
<th>Breaker Rated Short Circuit Current (kA RMS)</th>
<th>Breaker Continuous Current Rating (Amps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1200</td>
</tr>
<tr>
<td>4.76</td>
<td>29 - 50</td>
<td>1200</td>
</tr>
<tr>
<td>4.76</td>
<td>63</td>
<td>1200</td>
</tr>
<tr>
<td>8.25</td>
<td>33 - 40</td>
<td>1200</td>
</tr>
<tr>
<td>8.25</td>
<td>50 - 63</td>
<td>1200</td>
</tr>
<tr>
<td>15</td>
<td>18 &amp; 20</td>
<td>1200</td>
</tr>
<tr>
<td>15</td>
<td>25 - 40</td>
<td>1200</td>
</tr>
<tr>
<td>15</td>
<td>50 - 63</td>
<td>1200</td>
</tr>
</tbody>
</table>

**Footnote —** The capacitor bank rating is subject to the following conditions:

1. The transient voltage from line-to-ground, shall not exceed 3 times the maximum design line-to-ground crest voltage measured at the breaker terminals.
2. The number of re-strikes or re-ignitions shall not be limited as long as the transient voltage to ground does not exceed the value given in footnote 1.
3. Interrupting time shall be in accordance with the rated interrupting time of the circuit breaker.
4. Maximum Capacitor Bank KVAR rating is calculated as follows:

   
   \[
   \text{System Voltage (kV) x Cap. Switching Current (A) x } \sqrt{3}
   \] 

   
   1.25 (for ungrounded banks) or 1.35 (for grounded banks)

5. For Back-to-Back switching, the bank inrush currents are limited to 15KA at 2000hz.
6. For capacitor switching requirements other than shown above, consult GE.
AUTOMATIC TRANSFER

To improve system reliability and ensure supply to critical loads, primary or secondary selective system designs are often utilized. In these configurations, two or more otherwise typical radial buses are connected together via tie breakers. In normal operating mode, each bus is served by its own source through normally closed main breakers, with the bus tie breaker open. If an outage occurs on one of the incoming supplies, the incoming breaker connected to that supply is opened, and then the bus is re-energized by closing the bus tie breaker to transfer the dead bus to the live (alternate) source. To protect against damage to motors connected to the dead bus, the bus tie breaker is typically not allowed to close until the residual voltage on the effected bus has decayed to a safe level. After the lost source has been reestablished, the scheme provides two methods (auto and manual) to restore the system to normal configuration. If the sources cannot be synchronized, the bus tie breaker must be manually opened before the open incomer can be manually closed. In this procedure the incomer will only be allowed to close if the incoming source (line VT) voltage is above a 'live' threshold and the load (bus VT) voltage is below a 'dead' threshold value. If the sources are synchronized, it is possible to manually close the open incomer with synchcheck supervision to parallel all three breakers; the scheme will then automatically open a breaker which had been previously selected to trip if all breakers become closed, in this instance the bus tie breaker. Note that if momentary paralleling is utilized, the equipment and breakers must be rated for the total available fault current from the combined sources.

The detection of a undervoltage event and the resulting transfer logic can be accomplished using either discrete protective relays, auxiliary relays and timers, or with a PLC and programming, or by using the various protective relay and logic features contained in today’s multifunction relays, such as the GE Multilin SR750. In addition to a protective relay required for each of the three circuit breakers (both mains and the tie), it is required to connect one contact from a three-position switch to each breaker. This switch (device 43/10) is used to select the breaker that will trip after all breakers are closed. It is generally recommended that a two-position switch (device 43/83) with three contacts, be connected to each relay as an “Auto-Off” transfer scheme selector.

Because a relay is required for each the three circuit breakers, it allows bus-splitting operation. This is accomplished by setting the time overcurrent elements in the relay on the bus tie breaker to trip faster than the incomers, opening the bus tie before an incomer when operating from only one source.

FAST BUS TRANSFER

Fast bus transfer (FBT) is an option used when there is a need for transferring from a normal power source bus to an emergency or alternate power source upon failure of the normal source of power or vice-versa, as quickly as possible without paralleling, typically within a maximum of 3 cycles (50 milliseconds). It is utilized when serving essential loads such as motors and pump applications.

During this transfer, it is essential that bus “dead time” be as short as possible to prevent loss of downstream critical auxiliary functions, such as contactors and relays. It is important that the main and alternate breakers are not closed at the same time since the sources may not be synchronous or even if they are, some short circuit conditions may result in the loss of both sources, if they are both closed at the same time. Also, when both are closed at the same time, system short circuit currents can exceed the feeder breaker rating.
Circuit Breaker Selection

In order to provide the utmost assurance that one breaker will be open before the other is closed, accepted practice requires that the first breaker’s primary contacts have started to open before the second breaker is given a closing signal. “Fast” transfer means there is no intentional time delay in the transfer of a bus or load from one source of power to another.

Representative timing sequences using ML-18/18H breaker mechanisms for both standard and fast bus transfer equipped breakers are shown in Figures 3-1 and 3-2.

The amount of dead bus time depends upon whether the Power/Vac breaker is standard, or is equipped for FBT capability (provided with an early “b” (faster) contact and/or special closing coil). A breaker “b” contact is open when the breaker primary contacts are closed.

Fast bus transfer using Power/Vac circuit breakers with the ML-18 or 18H mechanisms do not utilize an early “b” contact. The standard “b” contact is already sufficiently fast - approximately 10 milliseconds from main contact part to “b” contact close. They are equipped with a special close coil, which reduces closing time to as little as 40 milliseconds.

Power/Vac circuit breakers with an ML-17 or 17H mechanism, a special early “b” contact is provided. This “b” contact closes 3 milliseconds after the vacuum interrupter main contacts open on the opening breaker, which initiates a closing of the second breaker. The other breaker (tie or incoming breaker) must have a special close coil that closes the main interrupter contact in approximately 50 milliseconds.

Typical dead times for fast bus transfer, using standard and special Power/Vac breakers for the ML-18 mechanism are shown in Table 3-5. Fast bus transfer is only offered for 1200, 2000 and 3000 ampere breakers having 125 VDC or 250 VDC control voltages.

Fast bus transfer breakers must be specified when placing an order. Fast Bus Transfer does not require the use of circuit breakers rated for 3-cycle interrupting, as interruption speed does not impact the amount of dead bus time.

<table>
<thead>
<tr>
<th>Power/Vac Breakers</th>
<th>Mechanism</th>
<th>Control Voltage (volts) (1)</th>
<th>Nominal Dead Bus Times (Milliseconds) Trip then close using:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Early “b” contact &amp; Special closing coil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No Arcing (2)</td>
</tr>
<tr>
<td>All Rating</td>
<td>ML-17</td>
<td>125/250 DC</td>
<td>62</td>
</tr>
<tr>
<td>All Rating</td>
<td>ML-18</td>
<td>125/250 DC</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Footnotes:
(1) Control voltage at rated value.
(2) Main contact parting to main contact making.
(3) End of arcing to main contact making.
Dead bus times noted include allowable + operational tolerances.
Section 3

Figure 3-1
ML-18/18H Transfer Timing Sequence - 5 Cycle Interrupting - Standard Close Coil

*Dead Bus and Closing Times can Vary Based on Allowable Tolerances. Opening - 32-45 ms. Closing 60 +/- 15 ms.

Figure 3-2
ML-18/18H Fast Bus Transfer Timing Sequence - 5 Cycle Interrupting - FBT Breaker with Special Close Coil

SERVICE CONDITIONS

Power/Vac metalclad switchgear ratings and capabilities are based on operation under certain specific service conditions, defined by ANSI as “usual.” Conditions other than usual are considered “unusual” or “harsh.” Factors used to classify service conditions are altitude, ambient temperature, and a variety of others, such as the presence of atmospheric contaminants, unusual storage conditions, and requirements for tamper-resistance. These factors are specified for circuit breakers in ANSI-C37.04-1999 (Circuit Breaker Rating Structure) and for equipment in ANSI-C37.20.2 -1999 (Metalclad Switchgear), and are summarized here for application guidance.

Application of Power/Vac circuit breakers under conditions other than “usual” may require significant derating, special construction or use of special protective features.

USUAL SERVICE CONDITIONS

Power/Vac circuit breakers (and switchgear assemblies) are suitable for operation at their standard nameplate ratings:

- Where ambient temperature is not above 40°C or below -30°C (104° F and -22° F)
- Where the altitude is not above 1000 meters (3300 feet).

NOTE: For switchgear assemblies (breakers and housings combined) there is one additional stipulation:

- Where the effect of solar radiation is not significant. (See Ref. 5 on page 3-14.) Where radiation is significant the user is responsible for specifying the cooling/ventilation required to limit the temperature rise.

UNUSUAL SERVICE CONDITIONS

Abnormal Temperature

The planned use of Power/Vac circuit breakers and switchgear outside the normal ambient temperature range (-30°C to +40°C) shall be considered special. Reference should be made to ANSI C37-20.2, Table 10. Example: if installed in a 50°C ambient temperature, the switchgear continuous current ratings must be derated by 8%, per ANSI Table 10. Such applications of increased temperature should be referred to GE for evaluation.

Temperature Rise

Per the ANSI C37.20.2 standard, the temperature rise of buses and bolted connections under rated full load current in an enclosed switchgear assembly, above the ambient air temperature outside the enclosure, must not exceed 65°C, and the total hot spot temperature must not exceed 105°C. Connections to insulated cables must not exceed a 45°C temperature rise, and a 85°C hot spot temperature when operated at rated continuous current in rms amperes at rated frequency.

The maximum rated ambient temperature is 40°C. The temperature of the air surrounding all devices in an enclosed switchgear assembly, considered in conjunction with their standard rating and loading as used, will not cause these devices to exceed their maximum allowable temperature when the switchgear assembly is surrounded by air at the maximum average ambient temperature of 40°C.

The average temperature of the air surrounding primary insulated cables in any compartment of an enclosed switchgear assembly will not exceed 65°C when the assembly is equipped with the maximum rated current devices for which it is designed.
High Altitude

Medium voltage metal-clad switchgear is designed and tested in conformance to ANSI Standards. Inherent is these standards is the use of air as a heat transfer and dielectric medium. In the application of metalclad switchgear at high altitudes, there are two characteristics which degrade above 1000 meters (3300ft). They are the continuous current rating and the dielectric withstand capability, which may result in excessive corona at operating voltages and an inability to operate due to the dielectric breakdown of the air insulation due to the reduced air density.

Power/Vac circuit breakers and switchgear assemblies utilize air for an insulating and cooling medium. Operation at altitudes above 1000 meters (3300 ft) will result in a higher temperature rise and lower dielectric withstand capability because the air is thinner at the higher altitudes. For applications at higher altitudes, the rated 1 minute power-frequency withstand voltage, the impulse withstand voltage, and continuous current rating of the switchgear should be multiplied by the correction factors listed in Table 3-6 to obtain the modified or derated ratings.

When the Voltage Correction Factor is applied to the maximum designed voltage rating of 15 kV, 8.25kV or 4.76 kV for metal-clad switchgear, the derating may not permit the equipment to be installed at altitudes above 1000 meters, at their respective typical nominal system voltages.

Since it is more realistic to apply these correction factors to the BIL rating (impulse withstand voltage) of the switchgear, an industry accepted option is to apply the equipment at their rated nominal voltages, with no change in clearances, by the addition of lighting arresters to protect the equipment.

The recommended practice is to apply the Voltage Correction Factor to the rated BIL level of the equipment, and provide surge protection on the load side of the switchgear using station type lightning arresters (Tranquell® arresters), selected such that the maximum discharge voltage of the arrester is about 20% less than the modified impulse voltage rating of the switchgear. (See ANSI C37.010-1999, 4.2.2)

The Current Correction Factor is applied to the continuous current rating of the equipment only. It is necessary to derate the continuous current rating, because switchgear assemblies depend on the air for cooling and will have a higher temperature rise when operated at altitudes above 1000 meters. The short-time and interrupting current ratings on vacuum breakers are not affected by altitude. Since the Current Correction Factor is small and the actual continuous current duty is usually less than the equipment rating, current correction is typically not as serious a consideration as the voltage correction. An additional consideration is that often at higher altitude, the ambient is reduced, which can offset the higher altitude continuous current derating effect.

NOTE: The recommendations are subject to modification depending on the actual system conditions.
Circuit Breaker Selection

Table 3-6
Altitude Correction Factors for Power/Vac Circuit Breakers and Switchgear

<table>
<thead>
<tr>
<th>Altitude (feet / meters)</th>
<th>3300ft - 1000m</th>
<th>4000ft - 1200m</th>
<th>5000ft - 1500m</th>
<th>6000ft - 1500m</th>
<th>7000ft - 2100m</th>
<th>8000ft - 1500m</th>
<th>9000ft - 1500m</th>
<th>10000ft - 3000m</th>
<th>12000ft - 3600m</th>
<th>13000ft - 4000m</th>
<th>14000ft - 4300m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Continuous Current</td>
<td>1.00</td>
<td>0.995</td>
<td>0.991</td>
<td>0.987</td>
<td>0.985</td>
<td>0.970</td>
<td>0.965</td>
<td>0.960</td>
<td>0.950</td>
<td>0.940</td>
<td>0.935</td>
</tr>
<tr>
<td>Rated Voltage</td>
<td>1.00</td>
<td>0.98</td>
<td>0.95</td>
<td>0.92</td>
<td>0.89</td>
<td>0.86</td>
<td>0.83</td>
<td>0.80</td>
<td>0.75</td>
<td>0.72</td>
<td>0.70</td>
</tr>
</tbody>
</table>

* From ANSI C37.20.2 - 1999, Table 8.

Application of metal-clad switchgear above 1000 meters (3300 ft) should be referred to GE. It should be cautioned that the correction factors of power transformers are different than those for switchgear.

Besides abnormal temperature and high altitude there are other unusual service conditions, which may require special protecting features or affect construction. Some of these are:

- Exposure to corrosive atmosphere, explosive fumes, excessive dust (e.g., coal dust, paper fibers) or particulate contamination, salt spray, steam, dripping water, and other similar conditions.
- Exposure to abnormal vibration, shock, unusual transportation, or special storage conditions.
- Installations accessible to the general public.
- Special duty/operating requirements of equipment.

BREAKER MOUNTED ACCESSORIES

Each Power/Vac breaker has two “a” and three “b” breaker auxiliary contacts wired from the breaker-mounted auxiliary switch for the Purchaser’s use. Additional breaker contacts from optional compartment mounted switches are available, see Section 7.

A redundant tripping circuit on Power/Vac circuit breakers can also be furnished via an optional second or “dual” trip coil. This option was designed specifically for use on utility breakers and on breakers applied in power-station switchgear applications. This feature is seldom used in industrial or commercial applications since the standard Power/Vac trip circuit is extremely reliable.

Power/Vac circuit breakers can be provided with an optional direct-acting undervoltage trip device. The undervoltage trip device is a factory
installed unit, which is an integral part of the breaker mechanism. Its function is to monitor the trip circuit control voltage and to mechanically trip the breaker if that control power drops below a preset value. (See page 4-5.) Refer to Instruction Book GEK-105393 for additional details.

Note that the options for a dual trip coil and the undervoltage trip device are mutually exclusive. Both cannot be utilized on the same breaker.

Standard Power/Vac design uses a lift truck, for lifting and inserting/removing the circuit breakers from the breaker cells. For designs using only 1-high breaker arrangements, with the breakers located in the bottom compartments, GE offers an option for roll-in breakers. Roll-in breakers have a wheeled undercarriage bolted to the bottom of the breaker frame, which raises the breaker to the proper height to interface with the breaker cell connections. The breaker cell floor frame is modified to allow the breaker to roll directly from the finished floor into the cell, without the need for the lift truck described in the following section. Note roll-in breakers cannot be inserted into a “standard” breaker cell without removing the bolt-on undercarriage, and using the lift truck.

**BREAKER LIFT TRUCKS**

GE offers two basic styles of lift trucks for handling Power/Vac circuit breakers, ground and test devices, roll-out transformer trays and fuse roll-outs. The first is a double masted truck that is available with all swivel casters. As shown in Figure 3-3. This truck is compatible with indoor switchgear and is required to reach the upper compartment rollout on indoor equipment. The maximum handle load is 15 lb. with a 850 lb. load. The typical dimensions of the double masted truck are width 36.5 inches, depth is 47 inches (with arms extended 55.5 inches), and the standing height is 79.5 inches extendible to 137.5 inches. The legs at the base of the lift truck are adjustable in width from 31.5 inches to 58 inches. This allows the legs to be narrowed to the width of the breaker for moving through doorways. **Caution; while lowering the breaker from the cubicle to the floor the width of the legs must maintain a minimum width of 44 inches.**

The single-mast lift truck can be collapsed for storage. The width is 39 inches with arms and legs collapsed, the depth is 29 inches and the height is 77 inches.
Both style of lift trucks are provided with interlocks to retain the device being handled and to lock the lift truck to the switchgear while a device is being inserted or removed. The carriage, which lifts a device, is raised or lowered by means of a winch and cable. When the winch handle is released the carriage is held in that position by means of a clutch-brake internal to the winch. Two arms are attached to the carriage for engaging the track rollers on the sides of each device.

The lift trucks are functional for both the upper and lower compartments of Power/Vac provided the equipment is mounted on no more than a 4 inch housekeeping pad. Pad cannot extend beyond the front frame of the equipment more than 3 inches.

Recommended minimum working access requirements for the lift trucks of indoor switchgear is a 78 inch front aisle space with an 18 inch right side and a 12 inch left side clearance. Outdoor switchgear requires a 66 inch front aisle space with a 36 inch left side and a 18 inch right side clearance required as standard minimum space. Smaller front aisles may be used if the required right side space is available but the factory must be consulted for an engineering evaluation.

Consult Instruction Book GEK-90214 for additional information on Lift Truck models and use.

REFERENCES

1. ANSI Standard C37.06-2000, Schedules of Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
11. Power/Vac Breaker Lift Truck, GEK-90214