Section 4

Control Power Equipment

Control Power Equipment

INTRODUCTION

This section of the Application Guide addresses specific control power requirements and provides guidance in selecting the proper type of control power equipment.

CONTROL POWER REQUIREMENTS

Equipment necessary to provide control power for Power/Vac switchgear must have sufficient capacity to deliver the maximum power required, at the proper voltage, under any operating condition.

The most important consideration in selecting a control power source is that it must provide tripping power for the circuit breakers during protective relay operation. Also, it should be capable of closing the breakers without direct manual operation. Other requirements can include:

DC
Indicating lamps
Relay power supplies
Emergency lights
Emergency motors
Excitation power (brushless motors, etc.)

AC
Indicating lamps
Relay power supplies
Equipment Heaters
Equipment Lights and Convenience Outlets
Excitation power (brushless motors, etc.)
Equipment ventilating fans
Remote lights (on structures, etc.)

All of these requirements must be considered in determining the type and rating of the control power source.

Sources of control power for Power/Vac metalclad switchgear are storage batteries (with charger) for DC control, and transformers for AC control. When AC is used for control, the tripping power is obtained from capacitors contained within trip devices, which are fed from rectified AC. The choice between these alternatives depends on factors such as the size of the switchgear installation, the need to operate breakers simultaneously, the degree of reliability required, expansion plans, the expected environmental conditions, maintenance support availability, and the economics related to these considerations.

CLOSING AND TRIPPING

Successful operation of Power/Vac metalclad switchgear depends on a reliable source of control power which will, at all times, maintain a voltage at the terminals of electrically operated devices within the rated operating voltage range. In general, the required operating range of the control power voltage in the switchgear equipment is determined by the rated operating voltage range of the circuit breaker. These ranges are established by ANSI C37.06 standards. Control voltage and operating currents for Power/Vac circuit breakers are given in Table 4-1 and 4-2.

Table 4-1 Control Voltage and Operating Currents for
Power/Vac ML-17 & 17H Breaker Mechanisms (Type VB)

Breaker Control Source Voltage	Closing Voltage Range	Tripping Voltage Range	Closing Coil Current		Tripping Coil Current		Charge Motor Inrush Current	Charge Motor Run Current (3)
			Standard	W/FBT	5 Cycle	3 Cycle		
48VDC	38-56VDC	28-56VDC	9.6	N/A	26.0	26.0	29.0	12.3
125VDC	100-140VDC	70-140VDC	6.0	32.0	10.2	6.0	18.3	3.7
250VDC	200-280VDC	140-280VDC	3.0	12.0	5.2	5.2	9.9	2.3
120VAC	104-127VAC	108-132VAC (1)	8.0	N/A	10.2	6.0	13.6	4.9
240VAC	208-254VAC	216-264VAC (2)	10.3	N/A	2.3	2.3	7.2	3.0

1. 120VAC control voltage for tripping requires the use of a 120VAC capacitor trip device. Cap trip device delivers 170VDC (peak) into a 125VDC trip coil.
2. 240VAC control voltage for tripping requires the use of a 240VAC capacitor trip device. Cap trip device delivers340VDC (peak) into a 340VDC trip coil.
3. Approximate spring charging time for ML-17 & ML-17H mechanisms is 7 seconds.
4. FBT = Fast Bus Transfer, requires special closing coil.

Table 4-2 Control Voltage and Operating Currents for
Power/Vac ML-18 & 18H Breaker Mechanisms (Type VB1)

Breaker Control Source Voltage	Closing Voltage Range	Tripping Voltage Range	Closing Coil Current		Tripping Coil Current		Charge Motor Inrush Current	Charge Motor Run Current (3)
			Standard	W/FBT	5 Cycle	3 Cycle		
48VDC	38-56VDC	28-56VDC	13.7	N/A	17.0	17.0	34.0	17.0
125VDC	100-140VDC	70-140VDC	6.0	35.7	5.9	10.5	23.0	8.0
250VDC	200-280VDC	140-280VDC	2.4	12.0	4.7	10.8	18.0	3.8
120VAC	104-127VAC	108-132VAC (1)	6.0	N/A	5.9	10.5	35.0	15.0
240VAC	208-254VAC	216-264VAC (2)	2.4	N/A	3.7	3.7	20.0	6.0

1. 120VAC control voltage for tripping requires the use of a 120VAC capacitor trip device. Cap trip device delivers 170VDC (peak) into a 125VDC trip coil.
2. 240VAC control voltage for tripping requires the use of a 240VAC capacitor trip device. Cap trip device delivers 340VDC (peak) into a 340VDC trip coil.
3. Approximate spring charging time for ML-18 & ML-18H mechanisms is 3 seconds.
4. FBT = Fast Bus Transfer, requires special closing coil.

Breaker Tripping

Tripping power availability should be independent of the voltage conditions present on the power system associated with the switchgear.

Power/Vac circuit breakers are provided with means for manual tripping (push button) and for electrically actuated tripping (trip coil). Electrically actuated tripping devices are used for two functions:

- As a means of opening the breaker in the process of normal switching operations initiated by an operator, or
- As a means of automatically opening the breaker for circuit protective purposes, under abnormal conditions.

Electrical tripping is accomplished when external power, from a battery or from a rectified AC source (with capacitor), is directed into the breaker trip coil. Normal circuit switching operations use an operator control switch to energize the trip coil. Automatic tripping occurs when a protective relay senses an abnormal system condition through the power circuit instrument transformers, and closes output contacts in the trip circuit.

When deciding between DC battery trip and AC capacitor trip, the following points must be considered:

- For a single breaker or a few breakers, AC control with capacitor trip devices may have lower cost than a battery system, but a separate trip device is required for each breaker and lockout relay.

- A battery source is more reliable, but requires more maintenance than a capacitor trip device. However capacitor trip devices also contain small rechargeable NiCad batteries, which must be checked and replaced periodically.

- If a battery is used for tripping, DC closing power can also be obtained for little additional cost.

- If non-self powered microprocessor relays are utilized for protection with AC control power, a small UPS should be included to ensure the relay power supplies remain powered-up during system disturbances or during transfers of the AC control power from normal to emergency source.

DC BATTERY TRIP—When properly maintained, a battery bank offers the most reliable tripping source. It requires no auxiliary tripping devices, and uses single-contact relays, which directly energize a single trip coil in the breaker. Power circuit voltage and current conditions during time of faults do not affect a battery-trip supply; therefore, it is considered the best source for circuit breaker tripping. Additional advantages are that usually, only one battery bank is required for each location, and it may be used to operate other equipment such as high-voltage circuit breakers or protective grounding switches.

Once a battery bank has been selected for tripping purposes, it can, after proper evaluation of additional loads, also be used for breaker closing power. For indoor applications, if the battery bank can be located close to the switchgear, a 48-volt battery operating level is usually suitable. For more general use, a 125-volt battery is recommended, but 250-volt batteries can be used if other conditions require that voltage.

General space requirements when the batteries are to be mounted in the outdoor (NEMA 3R) switchgear, are one 36 inch wide Power/Vac stack for a 48VDC battery bank and two 36 inch wide Power/Vac stacks for a 125VDC bank. In aisle type outdoor construction, 36 inch wide empty “work-spaces” are added to house the battery system. Note on indoor (NEMA 1) applications, batteries are typically not located within the switchgear structure.

Long service can be obtained from batteries when they receive proper maintenance, are kept fully charged, and when the electrolyte is maintained at the proper level. For equipment in outlying locations where periodic battery maintenance would be difficult, the capacitor trip device may offer overall advantages.

Power/Vac AUTO-CHARGE CAPACITOR TRIP DEVICE— The GE/ITI Automatic Charging Capacitor Trip Device (CTDB-6) is used to trip circuit breakers and lockout relays when AC control power source is utilized. The CTDB-6 converts AC control bus voltage to DC voltage and stores enough energy to operate a lockout relay or trip a circuit breaker, often more than once. The CTDB-6, with batteries fully charged, will maintain a charge for a minimum of 3 days after the AC power has been interrupted. In normal operation, the batteries are trickle charged from the AC voltage source.

DC voltage is available from the unit for tripping immediately upon AC voltage power up. Capacitors do not need to be charged to have tripping voltage available on the output of the device. This is because the output is automatically fed from the full wave bridge rectified AC signal, or the charged capacitors, whichever is greater. Capacitor charge current is limited to protect the control power system from a large current in-rush. This feature allows the use of many CTDB-6 units from the same control power voltage source without coordination problems. Additionally, the CTDB-6 is self-protected from short circuit damage on the output. The Automatic Charging Capacitor Trip Device is provided on PowerVAC circuit breakers whenever AC control voltage is specified. GE offers models for both 120VAC and 240VAC control power sources.

DIRECT ACTING UNDERVOLTAGE TRIP DEVICE—Most Power/Vac circuit breakers can be provided with a 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 DC trip control voltage and to mechanically trip the breaker if that control voltage is lost. The UV device will also block closing of the breaker if the control voltage is not 80% or more of the nominal value.

NEMA Standard Publication No. SG4-1990 paragraph 3.9 requires the dropout range of undervoltage trip devices to be 30 to 60 percent of the rated voltage. The Power/Vac undervoltage device trips the breaker in the range of 15 to 60 percent of the nominal tripping control voltage.

Control Voltage	Tripping Range
48 VDC	7-29 VDC
125 VDC	19-75 VDC
250 VDC	38-150 VDC

Specifications, which require tripping to occur at some voltage higher than 15 percent of normal, should be provided with a voltage sensing relay to remove trip control voltage from the undervoltage trip device to assure breaker tripping at the desired voltage.

Breaker Closing

Closing power availability should also be independent of voltage conditions on the power system associated with the switchgear as with tripping. Accordingly, a DC battery bank is normally considered to be the most reliable auxiliary power source. Nevertheless, in many instances, the battery bank or other independent power source necessary to achieve this goal may require an investment, which is considered too high for the advantages gained. This is particularly true for small switchgear installations, consisting of only a few circuit breaker units.

NOTE: When equipment is initially installed and control power is first energized, all Power/Vac breakers that are in the connected position will immediately begin to charge their closing springs, which may overload an otherwise properly sized AC or DC source. It is recommended to either rack breakers in to the connected position one at a time after control power is established, or pull all the individual breaker close circuit fuse blocks/ disconnects prior to energizing the control power circuit.

Generally, the choice between DC closing power derived from a battery and AC closing power derived from a control power transformer is an economic one, dictated by desired system reliability. There are other factors, however, which also influence this choice. These are:

- Need to close breakers with the power system de-energized.
- Availability of housing space for a battery and its associated charging equipment.
- Estimated ambient temperature extremes and the effect on battery capability.
- Maintenance requirements for a battery and battery charger.
- Expected future equipment additions, which may affect the present choice of closing-power source.

When the closing mechanism is operated from AC, the current required is such that it can be taken from a control power transformer or a general-purpose or lighting source, internal or external to the switchgear. The energy for the next operation is stored in the springs as soon as the breaker is closed. To permit control switch or automatic initiation of closing, the AC source must also be present at the time of breaker closing to energize the spring-release solenoid (close coil). The Power/Vac breaker mechanism is also capable of manual operation, if necessary, both for charging the springs and for releasing them to close the breaker.

For any control power source used for breaker closing, the maximum closing load should be calculated using Table 4-1 and 4-2 values. Usually, only one breaker will be closed at a time, but the possibility of simultaneous closing of two or more breakers must be examined. This possibility will depend on the type of application and any special control requirements, such as load restoration. Simultaneous closing of two breakers could occur with multiple-breaker, motor starting equipment, or with automatic reclosing breakers. Also, on large installations, with several different control points, different operators could cause simultaneous manual operations.

INDICATING LAMPS

Position indicating lamps for each circuit breaker are operated from the trip fuses with DC closing power, or the closing fuses on either AC control or a “tripping only” battery. These lamps represent a small, but steady load, which is of concern particularly in DC applications. The total load is the sum of:

- One indicating lamp per breaker.
- Lamps used to supervise fuses of lockout relays, etc.
- Additional lamps, if any, used for remote indication in parallel with switchgear lamps.

Burden is usually 0.035 amperes per lamp, regardless of voltage, and is assumed to be carried (by the battery) for not more than eight hours.

EQUIPMENT HEATERS

On outdoor designs, moisture condensation is minimized through the use of strip heating elements. Heater elements are located in each breaker or auxiliary compartment and each cable compartment with a total of 300 watts per vertical section. Heaters are rated 300W at 240VAC, but are applied at half-voltage, which reduces heat output to 75 watts each for extended life and are protected by perforated metal guards to prevent inadvertent contact with the heater element. Heaters are supplied on indoor designs only if specified by the purchaser.

Heaters should be energized at all times to guard against condensation caused by wide ambient temperature excursions. Accordingly, heater switches or thermostats are provided in the heater circuit only upon customer request.

COMFORT HEATING

Comfort heaters for use in outdoor aisle-type Power/Vac installations, must be supplied by the Purchaser. A grounding-type receptacle, rated 250 volt AC, 20 amperes, is provided at each end of the aisle for portable comfort heater connection.

When sizing the AC control power source, allow 5000VA load at 240VAC for each heater receptacle intended for use.

RELAYING

With DC control power, allowance must be made for simultaneous tripping of two or more breakers. Requirements for simultaneous tripping depend first, on the number of breakers on the DC source, and second, on the kind of relaying. Based on probability considerations, a guide to the possible number of simultaneous tripping is given in Table 4-3.

Table 4-3
Simultaneous Breaker Tripping

Number of Breakers in lIneup	1	2	3-5	6-10	Above 10
Breakers Tripped By:	**Probable Maximum Number of Breakers Tripping Simultaneously**				
Time delay fault protection	1	1	2	3	(a)
Instantaneous fault protection	1	1	3	4	(a)
Undervoltage or bus differential (b)	1	1	All	All	All

(a) Depends upon operating conditions.
(b) Use of single undervoltage or bus differential relay for tripping all breakers.

Lockout relays, when present, as in differential relay circuits, require special treatment:

- With AC operation, a capacitor trip device must be included for operation of each lockout relay.
- With DC operation, the lockout (86) relay coil current must be added to the simultaneous breaker demand, since the relay does not cut itself off until after the breaker coils have been energized. A guide to GE Type HEA lockout relay coil current is:

Operating voltage (volts)	48 V	125 V	250 V
HEA relay coil current (amperes)	10.7 A	5.5 A	2.4 A

In addition, all solid-state relays unless “self-powered”, have internal AC or DC power supplies which must be included in the total steady-state load. VA burden for typical solid-state protective relays fall between 10VA and 35VA, depending on manufacturer and model. Consult the specific device manufacturer’s catalog.

FANS

On outdoor aisle-type Power/Vac switchgear, roof fans for aisle ventilation are available as an option. The standard fan uses a 1/3 hp single-phase motor, for operation from 120VAC only; allow 333 VA per fan.

Substation transformers associated with switchgear sometimes include fans. When energized from the switchgear control power source, the fan load must be included in the total burden on the source. Usually this is a 240-volt, single-phase load; from one to several kVA per transformer.

On indoor 4000A Power/Vac switchgear, 4000A rated breakers require forced-air cooling. Each 4000A breaker utilizes two fans, each drawing 6A at 120VAC or 3A at 240VAC.

LIGHTS

Outdoor Power/Vac switchgear, both aisle and non-aisle types, is provided with receptacles for 120-volt incandescent lamps. The control power allowance for these should be 100 Watts per vertical section.

Other lighting loads, such as outside floodlights, must be factored into the AC control power load based on actual requirements.

CONVENIENCE OUTLETS

In outdoor Power/Vac switchgear, 115-volt duplex grounding convenience outlets are provided.

With aisle-less design, one outlet is provided per vertical section. With aisle-type construction, one outlet is located at each end of the aisle.

Control power allowance should be a nominal 500 Watts for each duplex outlet.

EXCITATION POWER

When synchronous motors with brushless field excitation are controlled directly from the switchgear, power for the exciter field source is sometimes required from the switchgear control power source.

This excitation demand varies with the machine, from 1 to perhaps 8 amperes DC, usually at approximately 100 volts. With rectified AC supply to the field, the AC equivalent of the DC field current must be included the total CPT loading. (As a first approximation, multiply the DC amperes by 1.15 and convert to VA by multiplying this product by 125 volts.) When the exciter field is fed directly from the battery, the field demand, as a nominal 8-hour load, must be included in the DC steady load total.

Generators with static regulators usually require a separate transformer on the incoming leads of the generator breaker. This transformer is of the same epoxy-cast coil, dry type, as the switchgear CPT, but is located in its own rollout tray. Such dedicated transformers are not part of the regular control power loading.

BREAKER REMOTE RACKING

When the optional motor driven remote racking device is utilized, the load on the control power source is 4.5A for the120VAC model and 2.5A for the 240VAC.

OTHER LOADS

With DC control, when the charger is supplied from the switchgear AC control power transformer, the charger load must be included in the total AC demand. Using charger DC ampere rating as a base, some ratios of equivalent AC load at different supply and battery voltages are tabulated in Table 4-4.

Table 4-4

AC Supply Voltage	AC Load Factor for Charger Battery Voltage	
	48V	125V
115 V	75%	230%
230 V	38%	115%

For example, a 6-ampere charger, fed 115VAC, and supplying a 125VDC battery bank, has an AC load of approximately 13.8 amperes (6 A x 230%) at full output, or 1590 VA (13.8 A x 115 V). While this would be an intermittent condition, with the normal load being about 0.5 to 1.0 amperes DC, the AC control source must be sized to handle the 13.8 ampere load.

With automatic control schemes, some relays will be energized continuously after the first breaker is closed. The amperes drawn by these relays must be totaled and included with the indicating lamp load, etc., to arrive at the total steady load.

Emergency loads on switchgear batteries, such as room lights or DC pump motors, usually result in a much larger battery bank than required for the switchgear alone. Lights are usually assumed to be used for three hours, and then extinguished. Motor load duration must be specified by the user.

CONTROL POWER SOURCE SELECTION

For a particular station, selection of a control power source may require sizing of a battery, a control power transformer, or sometimes both. The first step is to establish the size of each load of the various types discussed. Second, for batteries, the short-time loads, such as breaker tripping, and the steady load, such as lamps, must be converted to a common rate base.

With the relatively small demands placed on the control power source by individual breakers, as detailed in Table 4-1 and 4-2, other loads must be evaluated carefully, since they may represent the major demand. Particularly with batteries, long-time loads must have a time period stated, since a battery bank, with the charger "off", is not a "continuous" source.

DC CONTROL POWER EQUIPMENT

GE does not design, manufacture or test storage batteries. GE Switchgear Operations, when required, will select and furnish batteries and their charger as specified by the customer and in accordance with the requirements of the switching devices and the over-all station operation.

A DC control power source consists of a storage battery bank, rack and an associated charger. The battery bank is connected to the DC control power bus and the charger at all times. Large momentary loads are supplied from the battery bank, but it otherwise does very little work in normal operating situations.

The basic requirements of a storage battery are it must be capable of being trickle charged so that under normal conditions the battery is always fully charged and its terminal voltage held substantially constant. The trickle charge voltage must be less than the upper voltage limits of lamps and continuously energized coils and should not fall below a specified minimum voltage during maximum normal momentary discharge. This is to insure adequate closing voltage at the breaker mechanism terminals after making allowances for voltage drop in connections between the battery bank and the breaker mechanism.

Two types of batteries are used with switchgear that have the characteristics which meet the requirements for closing and tripping functions: lead-acid or nickel-cadmium. Several classes of each type are produced, each with different costs and with different ratios between short-time and long-time capacities. The exact type and class must be established before performing the conversion of loads to a common rate base.

Lead-acid Batteries

Common lead-acid battery types:

- Pasted plate, with lead-antimony grids.
- Lead-calcium; a pasted-plate construction with calcium replacing antimony as the additive for grid strength.

Pasted plate, lead antimony, is the basic lead-acid battery, familiar in another form as the automobile battery. For control work (compared to auto batteries), thicker plates and lower gravity of acid provide longer life and allow long-time trickle or "float" charging. With different plate thicknesses, expected life is from 6 to 14 years.

Lead-calcium construction has longer expected life (up to 25 years) than lead-antimony at a rather small increase in cost. The "pure lead" electrochemical characteristics, compared to the other classes, require slightly different (higher) charging voltages.

Nickel-cadmium Batteries

Nickel-cadmium batteries are more expensive than lead-acid, in general, but have advantages. Maintenance is less, life is longer, low-temperature discharge currents are higher for a given size, and they can be charged more rapidly.

Pocket-plate cells are the normal construction used with switchgear; they are made in three different plate thicknesses. The thickest plates are not suitable for short-time applications. Medium or thin-plate cells are used with switchgear; the choice depending upon the relative amounts, respectively, or long- or short-time load.

Sintered-plate construction, which is relatively new, is used mostly in "cordless" appliances, seldom in switchgear.

	Lead-Acid	NiCad
Initial Cost	Lower	Higher
Maintenance	Higher	Lower
Life Expectancy	Lower	Higher

Battery Capacity and Sizing

The capacity of a storage battery is usually expressed in ampere-hours (one amp for one hour, or the product of amperes output multiplied by hours of discharge, with the basic rate being eight hours). Battery capacity, however, may be expressed at many time-rates other than the eight-hour rate.

For switchgear short-time loads, such as breaker tripping, the one minute rate per cell (discharging to 1.75 volts for lead, or 1.14 volts for nickel-cadmium) is used. The one-minute rate does not exhaust the battery completely; rather, it is the rate which causes the terminal voltage to drop to the stated value early in the discharge period.

Further, the actual value of discharge capacity of a storage battery may vary over a wide range with battery temperature. Published data is for cells at 25° C (77° F), and battery rating factors must be reduced when the battery is at a lower temperature. For capacity rating factors refer to IEEE worksheets.

Generally the effect of high temperatures for every 15° F above 77° F the lead acid battery loses 50% of its useful life and for the same temperature decrease, the nickel-cadmium loses 20% of its useful life. The one-minute rating at -10° C (15° F), for instance is half the 25° C rating.

In calculating the battery loads you must consider three types of loads: Continuous loads are those that are energized for the duration of the duty cycle. These have a major effect of battery capacity. Non-continuous loads are energized for only a portion of the duty cycle. If the inception of the load is known, but the end is not or reverse, then you must consider it as the known portion of the duty cycle. Last are momentary loads which are very short in duration, they can be a fraction of a second, but you must treat it as lasting one full minute.

- Direct use of specification sheets, or software programs, etc. from battery makers.
- Referral of data to battery manufacturers.
- Referral of calculated data to switchgear manufacturers.

For direct calculation, the battery is assumed to have carried its steady loads for eight hours, and then as the worst case subject to the maximum load involving the one-minute rate.

Indoor locations assume that the battery is at 25° C (77° F); outdoor locations at -10° C (15° F). A minimum size limit of cell is suggested to allow for unknowns: 20 ampere-hours for lead-acid, or 15 ampere hours for nickel-cadmium.

A small station, for example, with the battery located indoors, might have three breakers, with closing and tripping duty, and no steady load except the switchgear indicating lamps. Two of the breakers have instantaneous settings on their overcurrent relays, so that per Table 4-3 simultaneous tripping of these two breakers might occur. Steady lamp load, thus, is 0.035 A x 3 = 0.105 amperes. Maximum short-time loads, given for both 48-volt and 125-volt DC to illustrate procedure, are shown in Table 4-5.

Table 4-5 Battery Sizing Information

Control Voltage	48 VDC		125 VDC	
Battery System Voltage Range	42-56 VDC		105-140 VDC	
Breaker Mechanism Type	ML-18	ML-17	ML-18	ML-17
Breaker Quantity				
Breaker Close Current	13.7 Amps	9.6 Amps	6.0 Amps	6.0 Amps
Breaker Close Time	5 Cycles	5 Cycles	5 Cycles	5 Cycles
Breaker Trip Current	17 Amps	26 Amps	5.9 Amps	10.2 Amps
Breaker Trip Time	5 Cycles	5 Cycles	5 Cycles	5 Cycles
Spring Charge Inrush Current	34 Amps	29 Amps	23 Amps	18.3 Amps
Spring Charge Windup Current	17 Amps	12.3 Amps	8 Amps	3.7 Amps
Breaker Spring Charge Time	3 Seconds	8 Seconds	3 Seconds	8 Seconds

Example:

Control voltage, DC	48 V	125 V
ML-18 Trip coil current	17 A	5.9 A
ML-18 Spring motor current	17 A	8 A

Since two breakers can trip at once in this example, maximum current from this load is either 17A x 2, or 5.9A x 2, respectively, 34 or 11.8 amperes total at 48 or 125 volts. Comparing this with charging motor current, we see that the trip current is larger, so trip current will be used in the next step as illustrated in Table 4-6.

Table 4-6 Battery Sizing Example

Battery Type:	Lead-acid		Nickel-cadmium	
Control voltage (volts)	45	125	48	
Maximum 1-minute demand (amperes)	34	11.8	34	11.8
8-hr. equiv. of 1-min. demand (Max. demand divided by conversion factor*) (amp-hrs)	22.7	7.9	11.7	4.1
Lamp load (0.105A x 8 hrs.) (amp-hrs)	0.84	0.84	0.84	0.84
Total amp-hrs (8 hr. rate)	23.54	8.74	12.54	4.94

* Conversion factors to convert to "common rate base" (i.e., from one-minute rate to eight-hour rate) are: 1.5 for the lead-acid batteries (pasted plate); 2.9 for the nickel-cadmium batteries (thin plate or high rate). Please note that conversion factors vary by cell size; therefore, the factors used in this example are not applicable for batteries of other sizes.

Analyzing these totals, the lead-acid battery at 48 volts with a nominal ampere-hour rating of 30AH will be required. As an alternate at 125 volts, the minimum 20AH lead-acid battery will be sufficient. The minimum nickel-cadmium battery of 15AH will be sufficient at 48 volts and at 125 volts.

In addition, since the total ampere-hours required in each case is less than the ampere-hour capacity of the selected cell, reserve capacity is available. The matter of reserve capacity is largely related to how long the charger may be off. This no-charge condition has been known to last for several days. Thus, a "DC low-voltage alarm" option in the charger may be desirable to warn of such conditions.

For the same station, with the battery at outdoor temperatures, the one-minute demand must be doubled before converting to ampere-hours. The eight-hour rate needs a smaller increase of about 30 percent. Note that these conversion ratios generally decrease as cell size increases; hence, the approximate size of cell being considered must be determined before the conversion factors can be determined.

In arriving at the actual size of the battery bank, care must be taken to review the calculated amp-hours or cell requirement and then take into account the recommended design factor of 10% times the calculated values and then an aging factor of 25% times the calculated values. The combined sum of these calculations will provide the actual size of the battery bank.

Battery Chargers

Battery chargers have been built both as unregulated or “trickle” chargers, and as voltage-regulated chargers. The latter type provides longer life for the battery, particularly if it is a lead-acid battery. Voltage-regulated chargers are considered standard for switchgear applications.

The charger must be selected with an ampere rating sufficient to satisfy the simultaneous demand of the following three functions:

- Self-discharge losses of the battery.
- Steady load of the station: indicating lamps, relays, etc.
- Equalizing charges, or other high-rate output requirements.

The self-discharge or “trickle” current of a lead-acid battery starts at about 0.25 percent of the eight-hour rate, and increases with age to about 1.0 percent of that rate. Nickel-cadmium cells can be assigned a similar trickle current.

Steady load is made up of the long-time loads mentioned earlier in this section.

Equalizing charge is a monthly requirement for lead-acid batteries except for the lead-cadmium class. When the charger is first switched to the higher equalizing voltage, the battery demands current equal to about 20% of its eight-hour rate. Nickel-cadmium batteries do not require equalizing, but it is convenient to use the same numbers as for lead-acid in establishing the charger capacity to be used for occasional “boosting” of the nickel-cadmium battery.

In sizing the charger, the first number considered should be the steady load from the preceding battery calculations. Add to this load, the equalizing charge current. A quick way to find equalizing amperes is to divide the battery ampere-hour capacity (at the eight-hour rate) by 40. The sum of steady load and equalizing amperes is then compared with a list of battery charger ratings; select a charger with a rating that equals or exceeds this sum. The trickle current, unless known to be quite large, is usually covered by the margin between the standard charge rating and the sum of steady and equalizing loads.

Occasionally a battery is shipped “dry,” with electrolyte added at its destination. Such batteries require a “conditioning” charge after filling; the amperes needed for this are 25% of the eight-hour rate, but with no other load connected.

AC CONTROL EQUIPMENT

Application

To minimize the possibility of inadvertent interruption of control power for AC-operated Power/Vac switchgear, it is recommended that control power be derived from a separate transformer used only for control and other power requirements, which are directly associated with the performance of the switchgear. The transformer should be energized from that part of the main power system least likely to be de-energized.

Where the switchgear is energized from multiple sources of power, a control-power transformer is usually provided for each source, for operation of breakers associated with that source. Breakers such as feeder and bus-tie breakers not associated exclusively with any one source are supplied either from a transformer connected to the switchgear bus, or by control power transfer panel located in the switchgear, which automatically connects the AC control bus to an energized transformer.

Selection

With AC control, if breaker tripping power is being obtained from capacitor-trip devices, its demand need not be included in the control power transformer section. Similarly, closing demand is relatively small, except for the breaker spring-charging motors. The principal caution regarding closing demand is to review for conditions where two or more spring-charging motors may be energized at the same time.

NOTE: When equipment is initially installed and control power is first energized, all connected Power/Vac breakers will immediately begin to charge their closing springs, which may overload the otherwise properly sized AC source. It is recommended to either rack breakers in one at a time after control power is established, or pull the close circuit fuse blocks or close circuit disconnects prior to energizing the control power circuit.

Other loads, such as those listed on page 4-6, must be totaled and evaluated to determine their demand on the control power transformer. The total load is then compared to the available sizes of control power transformers, and the next larger size selected.

As an example, consider an outdoor, protected-aisle station having five breakers and one auxiliary compartment (in four vertical sections). Control of breakers is from local control switches. No ventilating fan is used, but 400 Watts are needed for remote lights. As shown in Table 4-7, the load is approximately 8 kVA, so the next larger available transformer (10 or 15 kVA) is selected.

Table 4-7 AC Load Estimating Example

Type of Load	Load (VA)
Indicating lamps (0.035A x 230V x 5 Breakers)	40
Equipment heaters (300 W x 4)	1200
Comfort heater (plug in)	5000
Equipment lights (100 W x 4)	400
Convenience outlets (500 W x 2)	1000
Remote lights	400
TOTAL	8040

GUIDE FOR ESTIMATING THE HEAT LOSS IN Power/Vac® SWITCHGEAR

When operating at nameplate rating, Power/Vac metalclad switchgear heat losses per vertical section may be estimated by adding the individual components of heat loss as indicated below.

Table 4-8

Breaker and Bus Work Per Vertical Section	Heat Loss In Watts
1-1200 AMP BKR	675
1-2000 AMP BKR	1335
1-3000 AMP BKR	2030
3500/4000 AMP BKR	2765
2-1200 AMP BKRS. STACKED	1220
1-1200 AMP & 1-2000 AMP BKR	1880

To the above figures add the following as they apply to the line-up.

Table 4-9

Each vertical section with simple (typical) relaying and control	150 watts
Each vertical section with complex relaying and control (Differential relaying, backup protective relays, etc)	330 watts
Each VT rollout	50 watts
Each CPT rollout up to 15KVA	600 watts
Equipment heaters if supplied (per section)	300 watts

To convert Watts to BTU'S:

Watts x 0.05688 = BTU'S per minute
Watts x 3.4128 = BTU'S per hour