WESTERN POWER DISTRIBUTION
Serving the South West and Wales

Company Directive

STANDARD TECHNIQUE : TP6K/3

Relating to the Selection and Assessment of 30V and 110V Substation Battery Systems

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1.0 INTRODUCTION

This document describes the process for sizing and specifying 110V D.C. and 30V D.C. substation batteries, chargers and distribution boards. Procedures are included for specifiying new, and for checking existing battery systems, and for ensuring that the voltage drop on the D.C. wiring is within acceptable limits.

48V and 24V battery systems associated with telecontrol equipment (e.g. RTUs, radios, transducers, control relays etc.) are out of scope of this document, but it is envisaged that the selection process for such equipment will follow the basic principles described in this standard technique. SCADA battery systems typically have a longer standby period (e.g. 72 hours).

2.0 GENERAL REQUIREMENTS

2.1 Standard Requirements

All new, and substantially modified battery systems shall satisfy the requirements of the latest versions of EE SPEC:24 (30V systems) or EE SPEC:25 (110V Systems), as appropriate.

The following standard requirements must also be met:

- Minimum standby period: 24 hours
- Ambient temperature for 110V systems: 15^{o}C
- Ambient temperature for 30V systems: 5^{o}C
- Aging factor: 1.25 (i.e. new batteries shall be oversized by a factor of 1.25 to account for the expected deterioriation in capacity over their lifetime).
- Maximum voltage drop on the D.C. wiring = 6V for 110V systems and 2V for 30V systems.

2.1.1 <u>Ampere Hour Capacity</u>

Batteries are often referred to by their ampere hour capacity, however this value depends on a number of other factors, including, the rate at which the battery discharges, ambient temperature and the cell voltage at the end of the discharge period. The following criteria shall be used specify the ampere hour capacity of a battery, unless otherwise stated:

(a) Lead Acid Batteries

- C_{10} Capacity (i.e. the Ah capacity when fully discharged at a constant current over a 10 hour period).
- Final cell voltage: 1.85V/cell.
- Ambient Temperature: 20^{o}C.

(b) NiCad Batteries

- C_5 Capacity (i.e. the Ah capacity when fully discharged at a constant current over a 5 hour period).
- Final cell voltage of 1.0V/cell.
- Ambient temperature of 20°C.

3.0 NEW BATTERY SYSTEMS

3.1 General

When a new battery system is required it is necessary to select an appropriate battery, charger and distribution board. It is also necessary to check that the voltage drop over the proposed D.C. wiring is within the limits specified above.

For the vast majority of applications a standard battery system can be selected**.** All new 110V battery systems that utilise valve regulated lead acid (VRLA) batteries must have at least two parallel strings of separately fused batteries, to provide additional security. If one battery fails then the healthy string will support the load, albeit with a reduced ampere hour capacity.

The process for selecting a new battery system is shown in the flow diagram (Figure 1) and is described in the following section.

3.1.1 Obtaining Initial Information

The first step is to obtain the following items of information:

- Nominal battery voltage.
- Substation standing load.
- Number of circuit breakers at the substation.
- Number of circuit breakers that can be expected to trip simultaneously.
- Details of the circuit breaker closing mechanisms.

(a) Nominal Battery Voltage

Major substations, 132kV, 66kV and 33kV substations (including primary substations) require 110V battery systems.

11kV and 6.6kV Distribution substations and master substations may either use 110V or 30V battery systems, depending on the requirements of the switchgear, protection and other ancillary equipment.

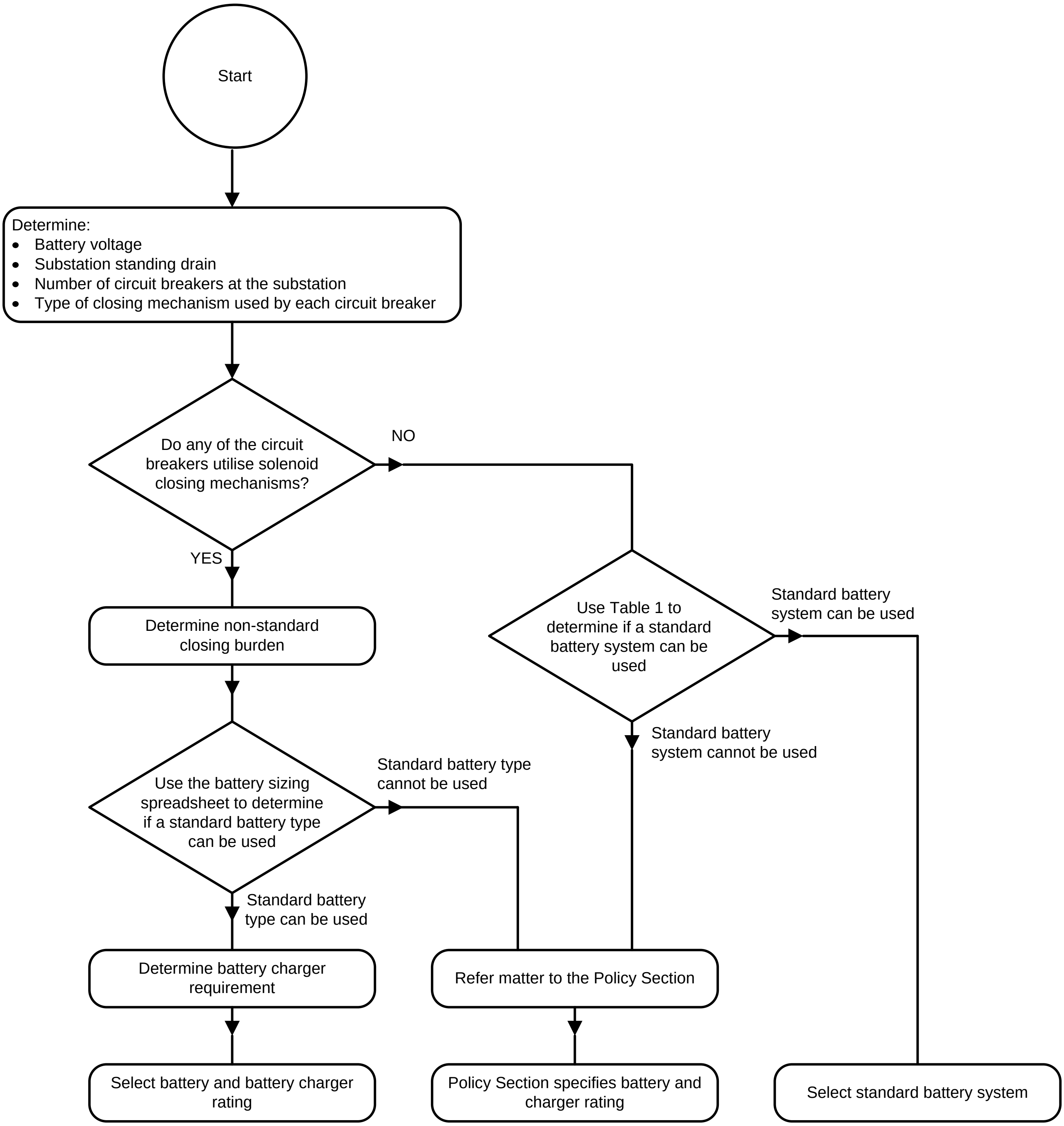


Figure 1 Process for Selecting a New Battery System

(b) Substation Standing Load

The standing load is the continuous electrical load in amperes that the battery is designed to supply. The standing load normally arises from the power requirements of solid state protection relays, circuit breaker control modules (such as used on FKI Eclipse and Horizon circuit breakers), permanently energised auxiliary relays, DC powered lamps, instruments and fault recorders.

Transient loads such as circuit breaker closing and opening duties and spring charging motors are not considered to be part of the standing load. Supplies to other non-protection related equipment (e.g. emergency lighting, tele-control RTUs etc.) must not be powered by the main substation battery. Tap-change control relays are normally powered from the AC voltage transformer and not from the substation battery system.

For new substations the standing drain can be calculated by adding together the current requirements for each protection relay and switchgear control module. Appendix A provides a list of standard relay types and their burdens.

At existing substations it may be simpler and more accurate to measure the standing load on the battery system, taking care to measure the total current in the DC circuits. If this approach is used an allowance should be made for future increases in standing load, particularly where it is expected that the substation, or its protection systems, will be modified in the future.

An example of a standing load calculation is included in Appendix D, Example D1.

(c) Number of Circuit Breakers and Type of Closing Mechanism

The number of circuit breakers and the closing mechanism used by each circuit breaker will have an impact on the switching duty that the battery must supply. Switching duty (comprising of short pulses of high current) can have a significant impact on the required ampere-hour rating of the battery.

The majority of circuit breakers utilise either spring charged closing mechanisms or magnetic actutor closing mechanisms. For the puposes of selecting a new battery system the following standard switching burdens can be assumed, unless one or more circuit breakers has a solnoid closing mechaism. It is not necessary to take account of D.C. spring charging motors as these have negligible impact on the battery rating.

Standard 110V Switching burden [1]

- Tripping = 550W (5A) for 0.5s
- Closing = 3000W (27.3A) for 0.5s

[1] Standard 110V burden is based on the relatively onerous requirements of Hawker Siddeley Switchgear Eclipse and Horizon circuit breakers.

Standard 30V Switching Burdens

- Tripping = 300W (10A)
- Closing = 400W (13.3A)

Circuit breakers with solenoid closing mechanisms normally have a much higher burden than conventional circuit breakers, often 12,500W or higher. In such cases the maximum switching burden must be determined before the battery capacity can be calculated. Information on the closing burden of a number of circuit breaker types is included in Appendix B but data may also be available from switchgear manuals. Where no information is available it is recommended that the close current is measured, either using a digital storage osciloscope (or an equivalent).

In order to convert a tripping / closing burden given in amperes to an equivalent closing current, the following equation is used:

Circuit Breaker Closing Burden (Watts) = Closing Current (Amperes) x Nominal Battery Voltage (e.g. 110V or 30V)

For example, if a cicruit breaker has 110V D.C closing solenoid with a closing current of 200A, the closing burden is 200A x 110V = 22,000W.

(d) Number of Circuit Breakers that can be expected to Trip Simultaneously

The highest current that a battery system may be expected to deliver often occurs when several circuit breakers trip simultaneously to clear a fault. The worst case condition shall be identifed and the number of circuit breakers that are required to trip simultaneously determined. Generally the worst case is for a fault on a bus-section circuit breaker or on a bus-coupler that requires two protection zones to clear.

3.1.2 Selecting a Standard Battery System

If none of the circuit breakers have solenoid closing mechanisms Table 1 can be used to select an appropriate battery type and charger rating, taking account of:

- Battery voltage
- Standing Load
- Number of circuit breakers at the substation
- Maxium number of circuit breakers that are expected to trip simultaneously.

If none of the standard batteries in Table 1 are suitable the matter should be referred to the Policy Section who will specify an appropriate battery type and charger rating.

All standard battery systems listed in Table 1 are included within WPD’s Term Contract for battery systems. Further information is included in the Purchasing Catalogue which is available from the Corporate Information Drive.

Standard Battery Type	Max. Standing Drain	Max. No. of Circuit breakers	Max. No. of CBs that can be Tripped Simultaneously	Min. D.C. Charger Rating
30V Systems				
1 String of Enersys Powersafe SBS31 Batteries	0.3A	3	3	4A
	0.5	2	2	
1 String of Enersys Powersafe SBS130 Batteries	1	50	13	15A
	2	50	9	
2 Strings of Enersys Powersafe SBS130 Batteries	4	50	18	32A
	5	50	14	
	6	50	10	
110V Systems				
2 Strings of Enersys Powersafe SBS B14 Batteries	2	100	25	10A
	3	100	15	
2 Strings of Enersys Powersafe SBS C11 Batteries	4	100	26	15A
	5	100	14	
2 Strings of Enersys Powersafe SBS 170F Batteries	8	100	26	27A
	9	100	18	
	10	100	10	

Table 1 Application of Standard Battery Types[1]

[1] Table 1 is not applicable for battery systems that supply circuit breakers with solenoid closing mechanisms. See clause 3.1.3 instead.

3.1.3 Selecting Battery Systems for Switchgear with Solenoid Closing Mechanisms

If the substation includes one or more circuit breakers that have solenoid closing mechanisms (or tripping and closing burdens in excess of the standard values listed in 3.1.1(c) then a detailed battery calculation shall be carried out using the following spreadsheet:

\\avodcs01\techncal\batteries\battery calculator.xls

The spreadsheet checks the capacity of battery sytsems and specifies the minimium acceptable rating of the associated charger. Guidance on using this spreadsheet is given in Appendix A.

For new battery systems, one of the standards battery types (listed below) should be used, where possible:

30V Systems:

- Single string (3 off 10V Blocks) of Enersys Powersafe SBS 31 Batteries
- Single string (5 off 6V Blocks) of Enersys Powersafe SBS 130 Batteries
- Two parallel strings (10 off 6V Blocks) of Enersys Powersafe SBS 130 Batteries

110V Systems:

- Two parallel strings (18 off 12V Blocks) of Enersys Powersafe SBS B14 Batteries
- Two Parallel strings (18 off 12V Blocks) of Enersys Powersafe SBS C11 Batteries
- Two parallel strings (18 off 12V blocks) of Enersys powersafe SBS 170F Batteries

If none of the standard battery systems satisfy the site requirements then a non-standard system will be required. Where this is the case the following information shall be sent to the Policy Section who will determine which battery type and charger rating shall be selected.

- Battery Voltage (110V or 30V)
- Standing Drain (Amperes)
- Total number of circuit breakers supplied by battery
- Number of circuit breakers using solenoid closing
- Details of the closing burden for each solenoid closing circuit breaker (in watts or amperes).

Note, all 30V and 110V battery systems shall statisfy the requirements of EE SPEC:24 or EE SPEC:25, as applicable.

3.1.3 Checking the Voltage Drop on the D.C. Wiring

Whenever a new battery system is specified the voltage drop on the secondary wiring shall be checked to ensure it is below the 2V limit (for 30V systems) or the 6V limit (for 110V systems). If the voltage drop is above the limit, the battery system will be unable to meet the required duty and it may not be capable of tripping and closing circuit breakers when partially discharged.

Normally, the worst voltage drop occurs when circuit breakers close or trip, since the trip and close coils / actuators draw relatively high values of current. The following two cases are should be considered:

(a) Closing a single circuit breaker. The worst case is normally for the circuit breaker located furthest from the battery system, however this is not always the case as it depends on the burden of each individual circuit breaker, the cross-section of the d.c. wiring and the length of the multicores.

(b) Tripping a number of circuit breakers simultaneously (e.g. due to the worst single fault condition). Typically this will be for a fault on a bus-section circuit breaker or bus-coupler that requires two protection zones to clear.

Resistance data for typical copper secondary wiring is included in Table 3.

Conductor Size (mm^2)	**Resistance (mΩ/m)**
1.5	12.1
2.5	7.41
4	4.61
6	3.08
10	1.83
16	1.15
25	0.727

Table 3 Resistance of Secondary Wiring

The voltage drop along a given length of conductor is calculated using ohms law, i.e. Voltage drop = Current (Amperes) x Resistance (ohms).

It should be noted that for a given length of multicore cable the voltage drop must multiplied by two to take account of the voltage drop on the positive (e.g. J1) circuit and also negative (e.g. J2) circuit. A detailed example of a voltage check is given in Appendix D, Example D3.

4.0 CHECKING EXISTING BATTERY SYSTEMS

4.1 General

Whenever electrical equipment, such as circuit breakers or relays, are added or repalced at a substation, and this is expected to increase the duty on the exisitng battery system, checks shall be made to ensure the battery has sufficient capapcity and the charger is adequately rated. In addition, if the changes are likely to make a significant difference to the voltage drop on the D.C. wiring then this shall also be checked.

4.1.1 Checking the battery and charger

The battery sizing spreadheet described in 3.1.3 is used to check the capacity of the existing battery charger and capcity. Guidance on using this spreadsheet is given in Appendix A.

Where the existing battery type is not listed in the spreadsheet the matter shall be referred to the Policy Section.

Where an exisiting battery charger is used with a new battery, checks shall be carried out to ensure it is suitable for the new battery. In particular the nominal voltage setting and the alarm settings shall be in accordance with the values specified in EE SPEC:24 and EE SPEC:25 respectively. Where a VRLA battery is used boost charging facilities must be disabled.

4.1.2 Checking the voltage drop on D.C. wiring

Where necessary, checks shall be carried to ensure the voltage drop over the D.C. wiring is within the limits specified in 2.1. Further information on carrying out such checks is given in 3.1.1 and Appendix D.

APPENDIX A

GUIDANCE ON THE USE OF THE BATTERY SIZING SPREADSHEET

A1 Introduction

A battery sizing spreadsheet has been developed to allow WPD staff to easily check whether substation battery systems have adequate capacity. The spreadsheet also calculates the minimum d.c. current rating of the battery charger, based on the battery capacity and standing load. The battery sizing spreadsheet is available form the following link:

\\avodcs01\techncal\batteries\battery calculator.xls

A2 Entering data

Data can be entered in any of the cells in the spreadsheet with a blue background (see Figure 2). A list of these cells is also provided below:

- Battery voltage
- Standby period (hours)
- Standing load (amperes)
- Tripping burden/s (watts)
- Closing burden/s (watts)
- Number of circuit breakers at substation
- Number of circuit breakers that may be tripped simultaneously
- Battery type (selected from list)
- Number of parallel strings of cells / blocks

When carrying out a battery systems calculation all of these fields should be checked and updated.

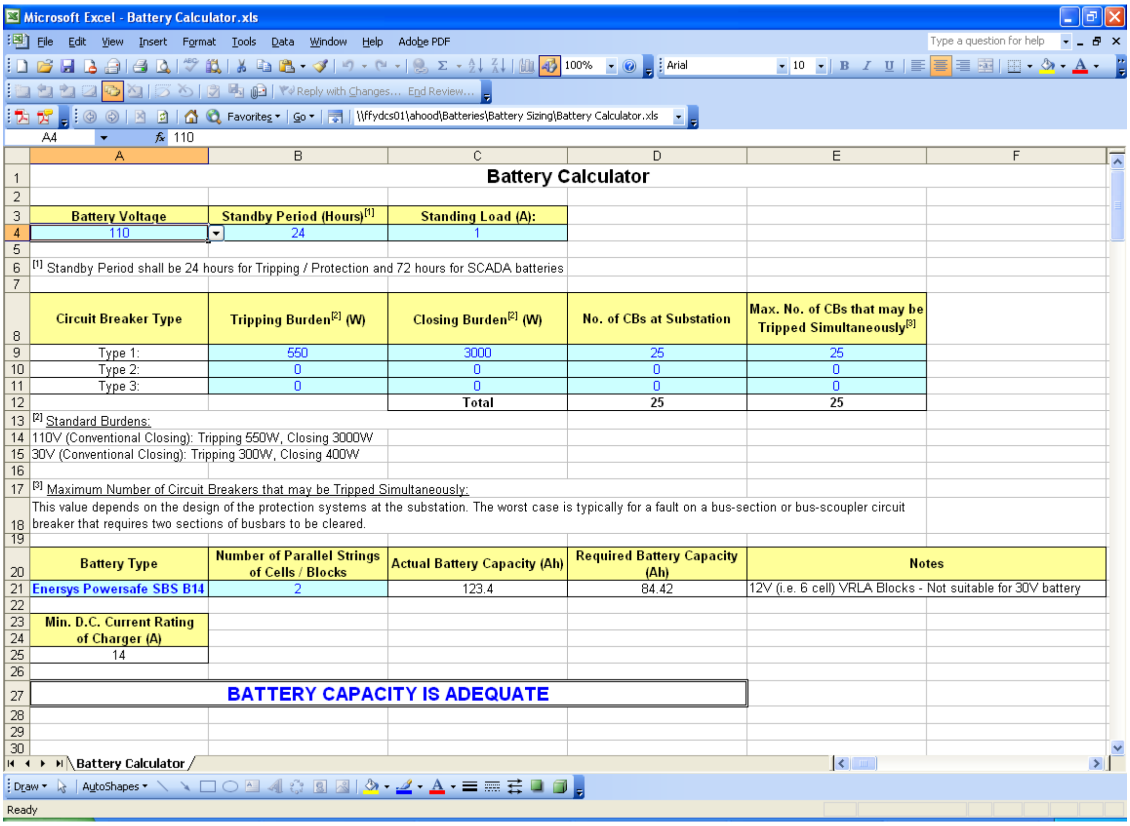
A2.1 Battery Voltage

For substation battery systems used for protection or tripping circuit breakers either 110V or 30V shall be selected, as appropriate.

A2.2 Standby Period

For all new and substantially modified substations a standby period (i.e. maximum period that the battery may be left without being charged) of 24 hours shall be selected.

Battery systems installed prior to April 2011 were designed with a standby period of 8 hours but if additional load is added to the battery system it shall be upgraded for a 24 hour standby period.



Microsoft Excel - Battery Calculator.xls

Battery Calculator

Battery Voltage	Standby Period (Hours)[1]	Standing Load (A):
110	24	1

[1] Standby Period shall be 24 hours for Tripping / Protection and 72 hours for SCADA batteries

Circuit Breaker Type	Tripping Burden[2] (W)	Closing Burden[2] (W)	No. of CBs at Substation	Max. No. of CBs that may be Tripped Simultaneously[3]
Type 1:	550	3000	25	25
Type 2:	0	0	0	0
Type 3:	0	0	0	0
		Total	25	25

[2] Standard Burdens:
110V (Conventional Closing): Tripping 550W, Closing 3000W
30V (Conventional Closing): Tripping 300W, Closing 400W

[3] Maximum Number of Circuit Breakers that may be Tripped Simultaneously:
This value depends on the design of the protection systems at the substation. The worst case is typically for a fault on a bus-section or bus-scoupler circuit breaker that requires two sections of busbars to be cleared.

Battery Type	Number of Parallel Strings of Cells / Blocks	Actual Battery Capacity (Ah)	Required Battery Capacity (Ah)	Notes
Enersys Powersafe SBS B14	2	123.4	84.42	12V (i.e. 6 cell) VRLA Blocks - Not suitable for 30V battery

Min. D.C. Current Rating of Charger (A)
14

BATTERY CAPACITY IS ADEQUATE

Figure 2 Battery Calculation Spreadsheet

A2.3 Standing Load

The standing load is the constant current used to power protection / alarm relays and circuit breaker control modules. Further guidance is included in 3.1.1 b) and in Appendix B.

A2.4 Tripping and Closing Burdens

The tripping and closing burdens for the different types of switchgear must be entered in watts. The spreadsheet allows up to three different tripping and closing burdens to be entered. The standard tripping and closing burden specified in 2.2.1 c) should be used for all circuit breakers with conventional motor wound spring mechanisms and 110V magnetic actuator closing mechanisms.

Where circuit breakers with solenoid closing mechanisms are used then the actual closing burden for the switchegar concerned must be used. Further guidance is given in 3.1.1 c) and in Appendix C.

A2.5 Number of Circuit Breakers at Substation

The number of circuit breakers at the substation associated with each tripping / closing burden shall be entered in the appropriate field. This allows the spreadsheet to estimate the number of switching operations that may be carried out during the standby period and hence the switching duty placed on the battery system.

A2.6 Number of Circuit Breakers that can be Expected to Trip Simultaneously

Under certain fault conditions it may be necessary to trip more than one circuit breaker at the same time to clear the fault. At most substations the worst case is considered to be for a fault on a bus-section circuit breaker or bus-coupler that requires two protection zones to clear.

Once the worst fault condition has been determined, the number of circuit breakers that are expected to be tripped simultaneously (by switching burden) shall be entered in the spreadsheet. The spreadsheet assumes that this switching event occurs at the end of the standby period (e.g. after 24 hours).

A2.7 Battery Type

The correct battery type shall be selected from the drop down list. If the required battery type is not listed then the matter should be referred to the Policy Section for further advice.

A2.8 Number of Parallel Strings of Cells / Blocks

The vast majority of traditional substation battery systems utilising vented lead acid or vented NiCad batteries use just one string of cells (as shown in Figure 3). All new 110V battery systems utilising valve regulated lead acid (VRLA) batteries require at least 2 strings of battery systems to provide additional resilience (see Figure 4). Parallel strings of batteries may also be used to increase the capacity of the battery. The number of parallel strings shall be entered in the calculation spreadsheet.

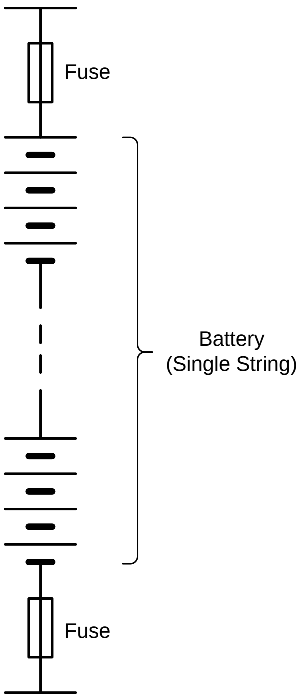


Figure 2 Single String Battery

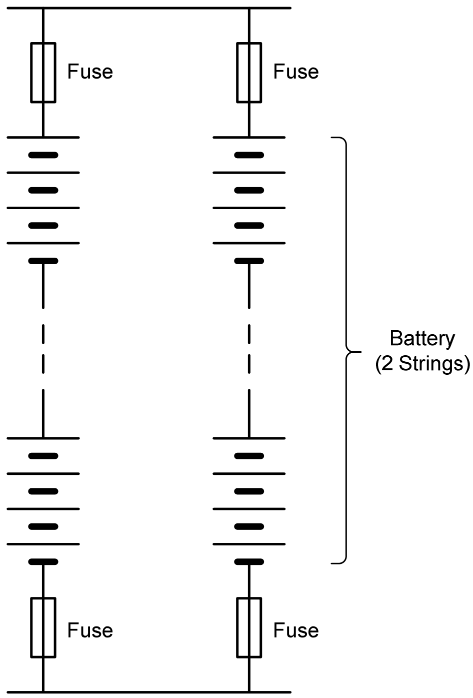


Figure 3 Double String Battery

A3 Results

The spreadsheet lists the capacity of the battery system that has been selected, taking account of the battery type and the number of battery parallel strings, and calculates the battery capacity that is required, based on that particular battery model. The spreadsheet also states whether or not the selected battery is adequate and provides additional information in the "Notes" column.

It should be noted that the required battery capacity will vary from one model of battery to another, since different battery types have different characteristics. For example, some battery types are suited to supplying a low current for a sustained period whilst others are better at delivering high currents for relatively short periods.

The spreadsheet also calculates the minimum D.C. charger rating for the standing load and battery that has been selected.

APPENDIX B

PROTECTION RELAY / CB CONTROL MODULE BURDENS

Table A1 Protection Relay Burdens

Manufacturer	Model	Burden (110V DC. system)	Burden (30Vd.c. system)
A-eberle	REG-DP	15W - power supply. 0.25W for each energised input. 17W is typical.	
Areva / GEC Alstom	Battery Alarm 300	2.2W	0.6W
Areva / Alstom GEC Alstom	GCM05	6W	
Areva / GEC Alstom	KAVR	2.5W to 12W depending on no. of energised outputs and inputs. 8W is typical.	
Areva / GEC Alstom	KAVS	4W	
Areva / GEC Alstom	KBCH	4.8W to 12W – depending on no. of energised outputs and inputs. 8W is typical.	
Areva / GEC Alstom	KCEG	4W to 12W – depending on no. of energised outputs and inputs 8W is typical.	4W to 12W – depending on no. of energised outputs and inputs 8W is typical.
Areva / GEC Alstom	KCGG	4W to 12W – depending on no. of energised outputs and inputs 8W is typical	4W to 12W – depending on no. of energised outputs and inputs 8W is typical.
Areva / GEC Alstom	KVTR	4W	4W
Areva / GEC Alstom	LFAA103	8.5W for power supply only 0.11W for each energised input 1.5W for each energised high duty output 0.4W for each energised low duty output	
Areva / GEC Alstom	LFCB102	10W quiescent 0.3W mean burden per input	
Areva / GEC Alstom	LFZP	10W for power supply 1.1W for each energised input (7 max) 14.4W is typical (assuming 4 inputs are energised)	
Areva / GEC Alstom	MVAS	5.6W	
Areva / GEC Alstom	MBCH	4W	

Manufacturer	Model	Burden (110V DC. system)	Burden (30Vd.c. system)
Areva / GEC Alstom	MBCI (Translay S)	1.9W	
Areva / GEC Alstom	MBCZ	3W to 4.5W per circuit breaker +3W per zone measuring unit +0.75 per isolator repeat relay +3W alarm unit 3W test unit	
Areva / GEC Alstom	MCGG22 MCGG42 MCGG52 MCGG62 MCGG82	2.5W 3.5W 4W 4W 5W	2W 3W 3.5W 3.5W 4.5W
Areva / GEC Alstom	MCHD04	2.5W	1.3W
Areva / GEC Alstom	MCRI	0.05W	0.05W
Areva / GEC Alstom	MCSU	3.75W	1.53W
Areva / GEC Alstom	MCVG61	11.5W	8.5W
Areva / GEC Alstom	METI11 METI12 METI13 METI31	6.8W 6.8W 6.8W 18.7W	2.2W 2.2W 2.2W 5W
Areva / GEC Alstom	MRTP	1W	0.5W
Areva / GEC Alstom	MVFU14 MVFU21	4.2W 3.75W	2.5W 1W
Areva / GEC Alstom	MVAX11 MVAX12 MVAX21 MVAX31 MVAX91	2W 1.9W 8W 8W 24W	2W 1.22W 3W 3W 9W
Areva / GEC Alstom	MVGC01	N/A (supplied from VT)	
Areva / GEC Alstom	MVTD	8W	2W
Areva / GEC Alstom	MVTI11 MVTI12	8W 9W	1W 2W
Areva / GEC Alstom	MVTP	3W	
Areva / GEC Alstom	MVTR51	1W Power supply only 0.2W per energised input approx 0.4W per energised output 2.4W is typical	0.8W Power supply only 0.2W per energised input 0.4W per energised output 2.2W is typical

Manufacturer	Model	Burden (110V DC. system)	Burden (30Vd.c. system)
Areva / GEC Alstom	MVTR52	1W Power supply only 0.2W per energised input approx 0.4W per energised output 7W is typical	0.85W Power supply only 0.2W per energised input approx 0.4W per energised output 6.85W is typical
Areva / GEC Alstom	MVTT14 MVTT15	7.5W 8.125W	0.5W 1.8W
Areva / GEC Alstom	MVTU11,12,13 MVTU18	8W 4.5W	1W 1.5W
Areva / GEC Alstom	MVTW01 MVTW03	N/A 3.5W	N/A 1.3W
Areva / Alstom / Schneider	P120 / P121	3W power supply only 0.25W per energised relay 1.1W per energised input 5W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 4.5W is typical
Areva / Alstom / Schneider	P122	3W power supply only 0.25W per energised relay 1.1W per energised input 6.2W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 5W is typical
Areva / Alstom / Schneider	P123	3W power supply only 0.25W per energised relay 1.1W per energised input 7.6W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 5.7W is typical
Areva / Alstom / Schneider	P125	3W power supply only 0.25W per energised relay 1.1W per energised input 6.2W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 5W is typical
Areva / Alstom / Schneider	P126	3W power supply only 0.25W per energised relay 1.1W per energised input 8.65W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 6.65W is typical
Areva / Alstom / Schneider	P127 / P127	3W power supply only 0.25W per energised relay 1.1W per energised input 8.65W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 6.65W is typical
Areva / Alstom	P141 / P142	10W is typical	10W is typical
Areva / Alstom	P143	12W is typical	12W is typical
Areva / Alstom	P441	15W is typical	
Areva / Alstom	P442	18W is typical	
Areva	P445	12.5W is typical	
Areva / Alstom / Schneider	P921	3W power supply only 0.25W per energised relay 1.1W per energised input 4.6W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 4W is typical

Manufacturer	Model	Burden (110V DC. system)	Burden (30Vd.c. system)
Areva / Alstom / Schneider	P922 / P923	3W power supply only 0.25W per energised relay 1.1W per energised input 7.3W is typical	3W power supply only 0.25W per energised relay 0.48W per energised input 5.4W is typical
Areva / Alstom	P941	10W is typical	10W is typical
Areva / Alstom	P942 / P943	12W is typical	12W is typical
Basler	BE1/81	8W maximum	
Hawker Siddeley	Eclipse Switchgear Control Module	7.7W	
Hawker Siddeley	Horizon Switchgear Control Module	7.7W	
GEC Alstom	SHPM101	25W	
Reyrolle / Siemens	Argus 1, 2, 4, 8	3W to 10W 6.5W is typical	3W to 10W 6.5W is typical
Reyrolle / Siemens	2DCC	1W	0.6W
Reyrolle / Siemens	2DAB	3W	0.76W
Reyrolle / Siemens	DAC	0.65W	0.25W
Reyrolle / Siemens	DAD	0.65W	0.25W
Reyrolle / Siemens	Duobias M	12W is typical	
Reyrolle / Siemens	GAD	0.6W	0.3W
Reyrolle / Siemens	MHR4	3W	
Reyrolle / Siemens	Omega	15W to 27W 21W is typical	
Reyrolle / Siemens	Solkor M	13W	
Reyrolle / Siemens	Supertapp RVM/4		
Siemens	7SJ61, 62, 63	5W is typical	5W is typical
Siemens	7SA61	5W is typical	5W is typical
Siemens	7SA522	5W is typical	5W is typical

APPENDIX C

KNOWN CLOSING SOLENOID BURDENS

Table B1 Closing Solenoid Burdens

Switchgear			Closing Coil Burden (W)
Manufacturer	**Type**	**Rating**	
South Wales Switchgear	C4X	All	8000
South Wales Switchgear	C8X	All	8000
South Wales Switchgear	D4X	250MVA / 6.6kV	14600
South Wales Switchgear	D4X	250MVA / 11kV	8000
South Wales Switchgear	D4X	350MVA / 11kV	12800
South Wales Switchgear	D4X4	350MVA / 11kV	15000
South Wales Switchgear	D4X6	250MVA / 6.6kV	15000
South Wales Switchgear	D8X	250MVA / 6.6kV	14600
South Wales Switchgear	D8X	250MVA / 11kV	8000
South Wales Switchgear	D8X	350MVA / 11kV	12800
South Wales Switchgear	D8X4	250MVA / 11kV	15000
South Wales Switchgear	D8X6	250MVA / 6.6kV	15000
South Wales Switchgear	D8/12X1	250MVA / 6.6kV	14600
South Wales Switchgear	D8/12X1	250MVA / 11kV	14600
South Wales Switchgear	D8/12X1	350MVA / 11kV	16300
South Wales Switchgear	D12X	350MVA / 6.6kV	16300
South Wales Switchgear	D20X1	350 MVA / 6.6kV	35000
South Wales Switchgear	D20X4	250MVA / 6.6kV	25000
South Wales Switchgear	D20X4	250MVA / 11kV	14600
South Wales Switchgear	D20X4	350MVA / 11kV	25000
Brush	VSI R4/1	250MVA / 11kV	10500
Brush	VSI R4/1	250MVA / 6.6kV	14600
Brush	VSI R4/1	350MVA / 11kV	14600
Brush	VSI R4/2	250MVA / 11kV	15200
Brush	VSI R4/2	350MVA / 11kV	15200
Brush	VSI R4/2	350MVA / 6.6kV	20800
Brush	VSI R8/1	250MVA / 11kV	10500
Brush	VSI R8/1	350MVA / 11kV	14600
Brush	VSI R8/2	250MVA / 11kV	15200
Brush	VSI R8/2	350MVA / 11kV	15200
Brush	VSI R8/2	350MVA / 6.6kV	20800
Brush	VSI R12/1	250MVA / 11kV	12800
Brush	VSI R12/1	350MVA / 11kV	14600
Brush	VSI R12/2	250MVA / 11kV	15200
Brush	VSI R12/2	350MVA / 11kV	15200
Brush	VSI R12/2	350MVA / 6.6kV	20800

BATTERY CALCULATION EXAMPLES

D1 Example D1 Selecting a Standard Battery System

D1.1 Scenario

A new 33/11kV substation will have 10 x outgoing 11kV circuits, two incoming 11kV circuits and an 11kV bus-section circuit breaker. In addition the substation has 5 x 33kV circuit breakers.

The 11kV circuit breakers are Hawker Siddeley Eclipse type and the 33kV circuit breakers are Hawker Siddeley Horizon, each of which is fitted with an electronic control module. None of the circuit breakers have solenoid closing mechanisms.

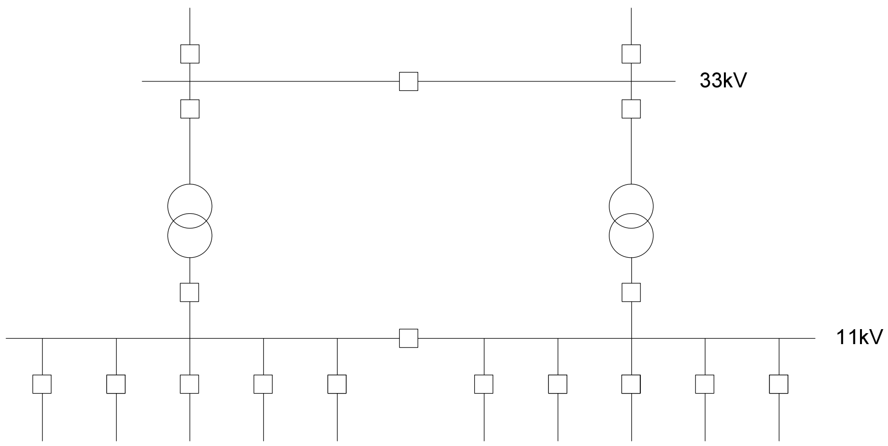


Figure D1

The following solid state protection relays are installed:

- 10 x 11kV outgoing feeders each fitted with one Areva P122 relay.
- 2 zones of 11kV bus-section protection fitted with one Areva P122 relay.
- 2 x 11kV incoming circuit breakers each fitted with one Areva P122 relays and one Areva P120 relay.
- 2 x 33kV outgoing feeders each fitted with one Areva P445 relay.
- 1 x 11Kv bus-section circuit breaker fitted with one Areva P122 relay
- 2 x 33kV transformer panels each fitted with one Areva P122 relay

D1.2 Calcualting Standing Load

The burden of the relays and control modules, taken form Appendix B, are listed below:

- 17 x Areva P122 relays with a burden of 17 x 6.2W = 105.4W
- 2 x Areva P120 relays with a burden of 2 x 5W = 10W
- 2 x Areva P445 relays with a burden of 2 x 12.5W = 25W
- 18 x circuit breaker control modules with a burden of 18 x 7.7 = 138.6W

This gives a total standard load of 279W.

A 110V battery system is to be used therefore the standing load = 279 / 110 = 2.54A

D1.3 Determining Number of Circuit Breakers at Substation

From the Figure D1 it can be seen that the number rof circuit breakers at the substation is 18.

D1.4 Type of Closing Burden

Hawker Siddeley Eclipse and Horizon switchgear utilise magnetic actuator closing.

D1.5 Maximum number of circuit breaker that may trip simultaneously

The wost case is assumed to be for a fault on the bus-section circuit breaker that requires thirteen 11kV circuit breakers to trip, plus two 33kV circuit breakers, therefore the maximum number of circuit breakers that may trip simultaenously is fifteen.

D1.6 Required Battery System

Using the Flow Chart in Figure 1, the substation does not have circuit breakers with solenoid closing therefore Table 1 can be used to detemrine the required battery type.

From Table 1 it can be seen that the standard battery system based on 2 strings of Enersys Powersafe SBSB14 batteries is adequate for a substation with up to 100 circuit breakers installed, a standing drain of 3A and up to 15 circuit breakers tripping simultaneously.

D2 Example D2 Checking an Existing Battery System

D2.1 Scenario

An existing primary substation has a total of eleven 11kV circuit breakers with solenoid closing mechanisms each with a 12,500W closing burden, and three 33kV circuit breakers with conventional spring charge closing mechanisms. The standing drain on the existing substation is 1A.

The existing battery consists of 55 Tungstone HBS13 vented lead acid (i.e. Planté) cells. The charger is a 20A, 110V constant voltage charger set with a float voltage of 125V and a boost voltage of 137V.

It is proposed to add four 11kV circuit breakers (utilising conventional spring charge closing mechanisms) to the board and to replace some of the protection, which will increase the standing load to 2A.

Once the additional circuit breakers have been installed, the maximum number of circuit breakers that may be expected to trip simultaneously will be seventeen (i.e. eleven 11kV solenoid closing circuit breakers, four conventional 11kV circuit breakers and two conventional 33kV circuit breakers).

D2.1 Required Battery System

The battery calculation spreadsheet must be used to check the exisitng battery capacity and charger rating. The following data is entered into the spreadsheet (see Figure D2.1):

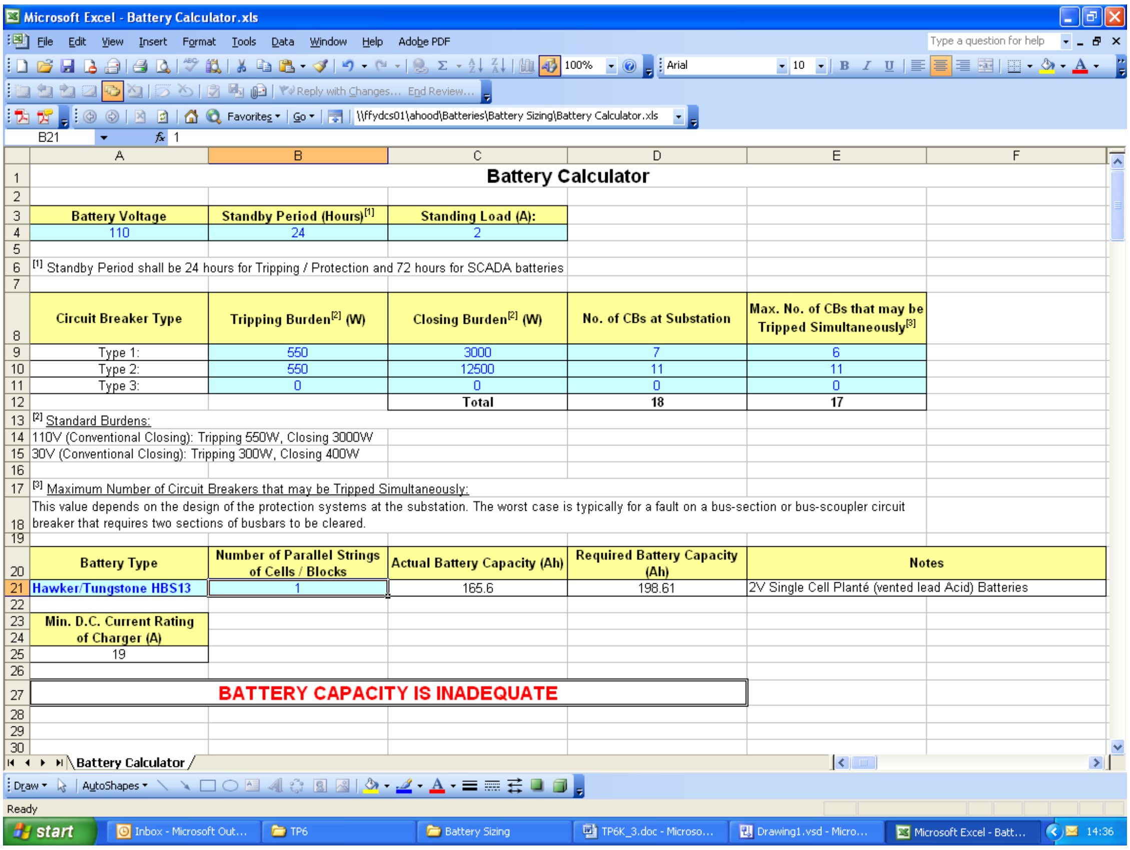
- Battery voltage = 110V.
- Standby period (hours) = 24 hours.
- Standing load (amperes) = 2A.
- Tripping burden/s (watts) = 550W (standard value).
- Closing burden/s (watts) = 12,500W for the solenoid CBs and 3,000W for other circuit breakers.
- Number of circuit breakers at substation = 18 (11 solenoid CBs and 7 conventional CBs).
- Number of circuit breakers that may be tripped simultaneously = 17 (11 solenoid CBs and 6 conventional CBs).
- Battery type (selected from list) = Tungstone HBS13.
- Number of parallel strings of cells / blocks = 1 (single string of cells).

It can be seen that the existing battery has a capacity of 165.6Ah and the required capacity for this type of battery is 198.61Ah. This means that the battery will have to be repalced before the new switchgear and protection is installed.

The new battery system should, as far as possible, be selected from the list of standard 110V batteries listed in 3.1.3. The smallest standard 110V system is based on two prallel strings of Enersys Powersafe SBS B14 batteries. When this battery type is entered in the spreadsheet (see figure D2.2) it can be seen that it has a capacity of 123.4Ah (substantially lower than the Tungstone HBS13) but the required battery capacity has dropped to 109.54Ah and so two strings of Enersys Powersafe SBS B14 are adequate for the modified substation. The spreadheet also shows that the charger must have a d.c. rating of at least 15A.

It should be noted that the reason that the valve regulated lead acid SBS B14 battery is suitable, despite having a significantly lower Ah rating than the existing Planté battery, is because it can deliver the high current needed to close the solenoid circuit breakers (and also trip the seventeen circuit breakers simultaneously) much more efficiently than the HBS13 battery can.

<u>Battery</u>



Microsoft Excel - Battery Calculator.xls

Battery Calculator

Battery Voltage	Standby Period (Hours)[1]	Standing Load (A):
110	24	2

[1] Standby Period shall be 24 hours for Tripping / Protection and 72 hours for SCADA batteries

Circuit Breaker Type	Tripping Burden[2] (W)	Closing Burden[2] (W)	No. of CBs at Substation	Max. No. of CBs that may be Tripped Simultaneously[3]
Type 1:	550	3000	7	6
Type 2:	550	12500	11	11
Type 3:	0	0	0	0
		Total	18	17

[2] Standard Burdens:
110V (Conventional Closing): Tripping 550W, Closing 3000W
30V (Conventional Closing): Tripping 300W, Closing 400W

[3] Maximum Number of Circuit Breakers that may be Tripped Simultaneously:
This value depends on the design of the protection systems at the substation. The worst case is typically for a fault on a bus-section or bus-scoupler circuit breaker that requires two sections of busbars to be cleared.

Battery Type	Number of Parallel Strings of Cells / Blocks	Actual Battery Capacity (Ah)	Required Battery Capacity (Ah)	Notes
Hawker/Tungstone HBS13	1	165.6	198.61	2V Single Cell Planté (vented lead Acid) Batteries

Min. D.C. Current Rating of Charger (A)
19

BATTERY CAPACITY IS INADEQUATE

Figure D2.1 Example D2 - Exisitng Tungstone HSB13

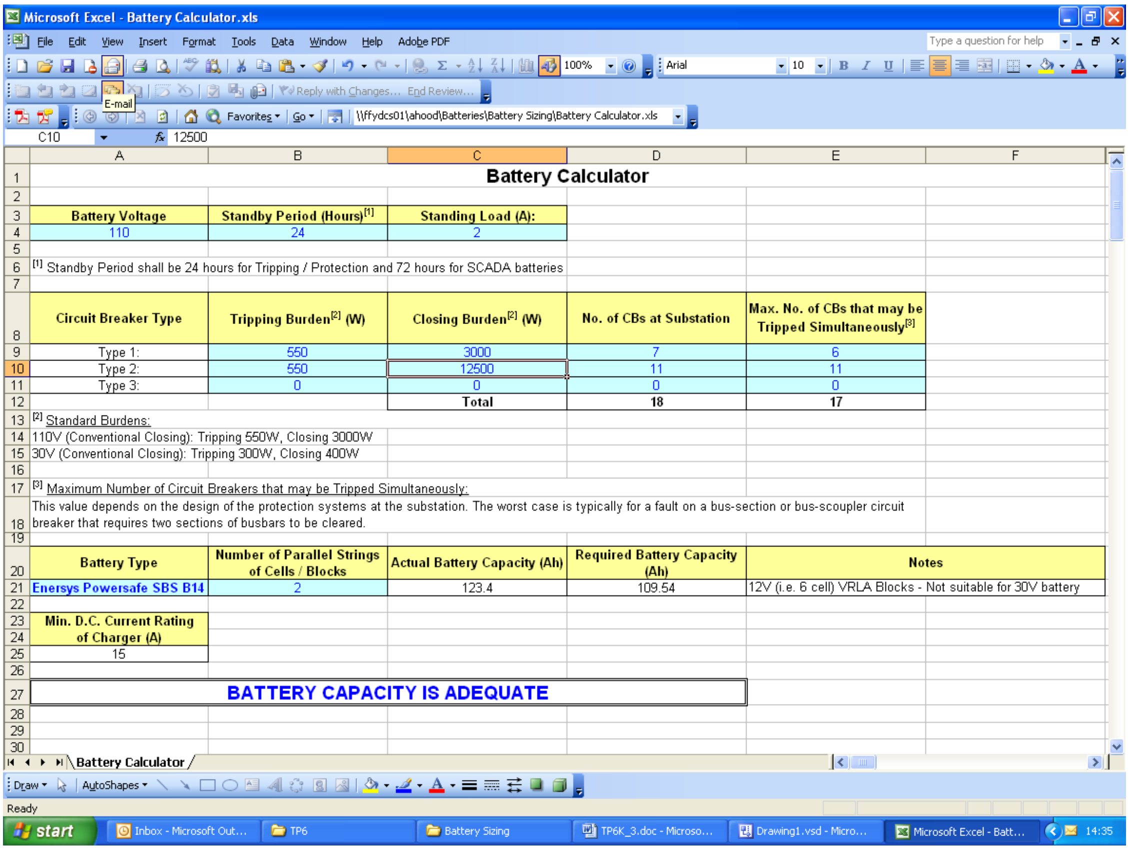


Figure D2.2 Example D2 - Proposed Enersys Powersafe SBS B14 Battery

D3 Example D3 Voltage Drop Calculation

D3.1 Scenario

An 11kV switchboard with 11 circuit breakers is shown in Figure D3.1. None of the circuit breakers have solenoid closing mechanisms.

The trip / close circuits consist of 6mm^2 copper cable (connected between the battery system and the individual circuit breakers, as shown in Figure D1. The resistance of this size of conductor is 3.08mΩ /m (derived from Table 3).

The closing and tripping burdens for the circuit breakers are derived from Table 2. The closing burden is assumed to be 3000W (i.e. 27.3A at 110V) and the tripping burden is 550W (i.e. 5A at 110V).

For the purpose of this example, the burden of the protection is assumed to be 11W per circuit breaker (i.e. 0.1A).

D3.1 Circuit Breaker Closing Calculation

The resistance of each part of the DC circuit is calculated using the conductor data from Table 3 and the dimensions in Figure D3.1. The highest voltage drop will occur when the most remote circuit breaker is closed. The burden of the protection relays should, strictly speaking, be included when carrying out this calculation (as shown in Figure D2).

(a) Simplified Calculation:

As the burden of the protection relays is very low, compared with the closing burden of the circuit breaker, a reasonable estimate of the voltage drop can be obtained by assuming that the entire relay burden for the switchboard (i.e. 11 x 0.1A = 1.1A) is connected at the most remote circuit breaker (i.e. CB1).

The resistance of the 22.8m length of $6mm^2$ cable = 22.8 x 2 x 3.08 = 140.45mΩ. The 2x factor takes account of the fact that the total circuit length (the positive circuit plus the negative circuit) is twice the length of the associated multicore.

The voltage drop is calculated using ohms law:

Voltage drop	=	Resistance x Current
	=	(27.27 + 1.1) x 0.14045
	=	3.98V

(b) Detailed Calculation:

A detailed calculation, taking account of the distributed nature of the protection burden has been carried out, for information. The results of this detailed calculation are summarised in Figure D3.2. This calculation gives a maximum voltage drop of 3.976V, just 0.004V lower than the value obtained from the simplified calculation.

The voltage drop derived from both the simplified calcualtion and detailed calcualtion are well below the maximum allowable value of 6V.

D3.2 Circuit Breaker Trip Calculation

The worst tripping condition is for a fault on the bus-section circuit breaker. This requires all 11 circuit breakers to trip simultaneously to clear the fault.

In this example the burden of each circuit breaker is 550W (5A at 110V). An additional 0.1A is added to each circuit breaker to take account of the burden of the protection relays.

In this case the resistance of each section of wiring and the current flowing in this wiring must be determined. From these values the voltage drop across each section is calculated using ohms law. These individual voltage drop values are added together to determine the total voltage drop at the most remote circuit breakers (i.e at CB1 and CB11). Figure D3.3 shows the results of these calculations.

In this example the highest voltage drop is 7.16V which is above the highest acceptable value of 6V for 110V systems.

If the 20m length of $6mm^2$ cable installed between the battery and bus-section circuit breaker were repalced with $10mm^2$ cable (that has a resistance of 1.83mΩ/m) the voltage drop across this section would be 4.11V instead of 6.91V. This reduces the voltage drop at CB1 and CB11 to 4.36V.

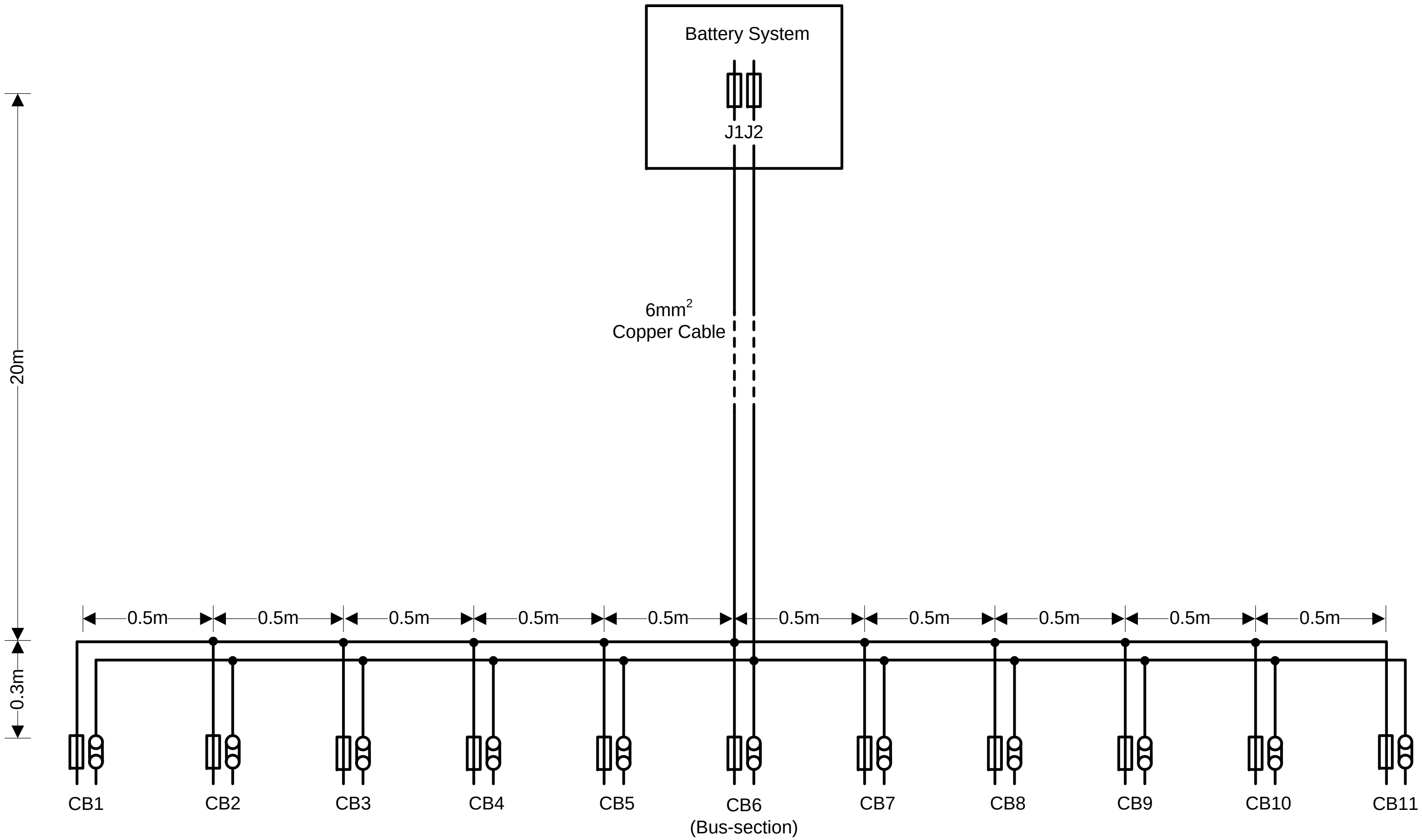


Figure D3.1 Voltage Drop Calculation - Circuit Breaker Secondary Wiring Layout

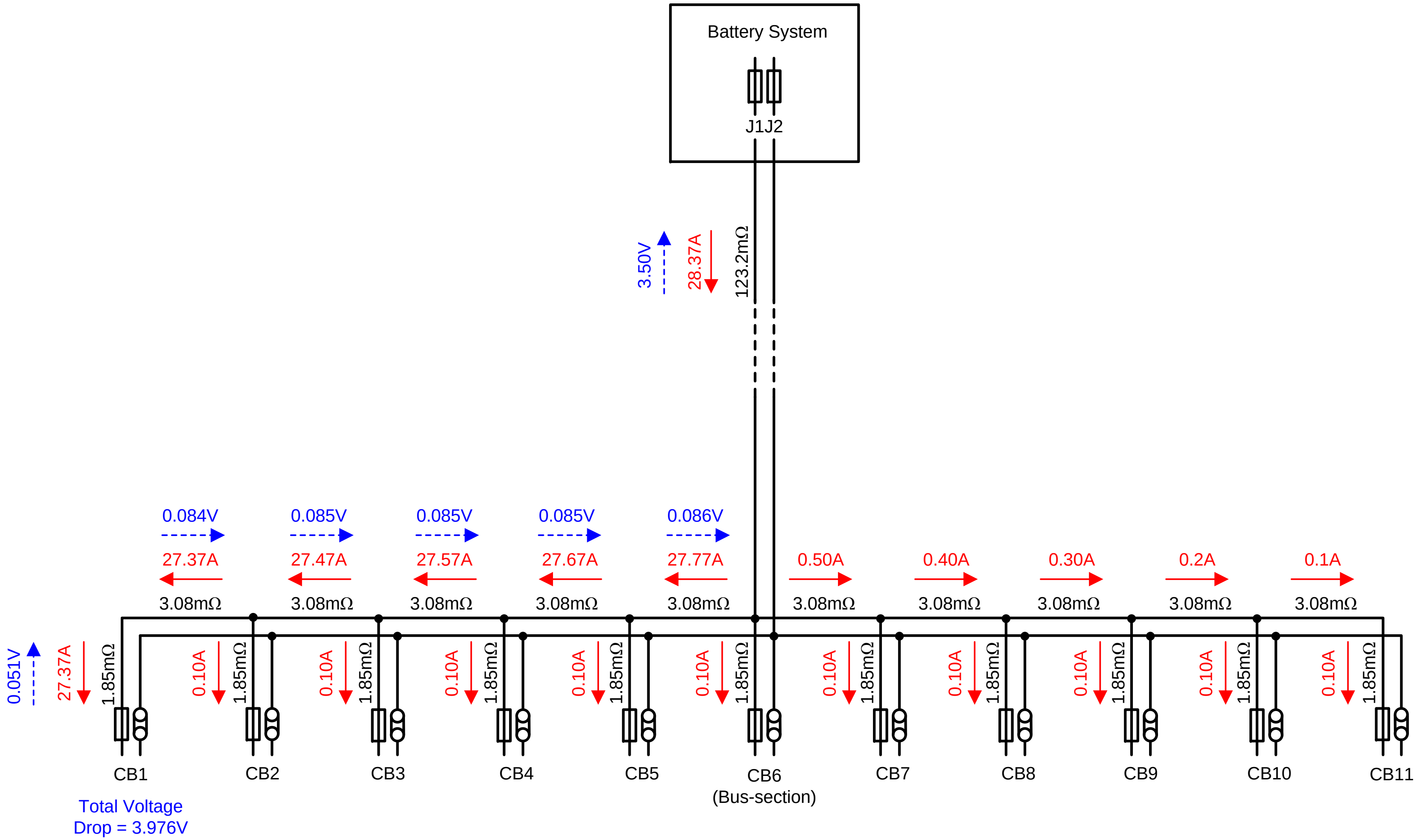
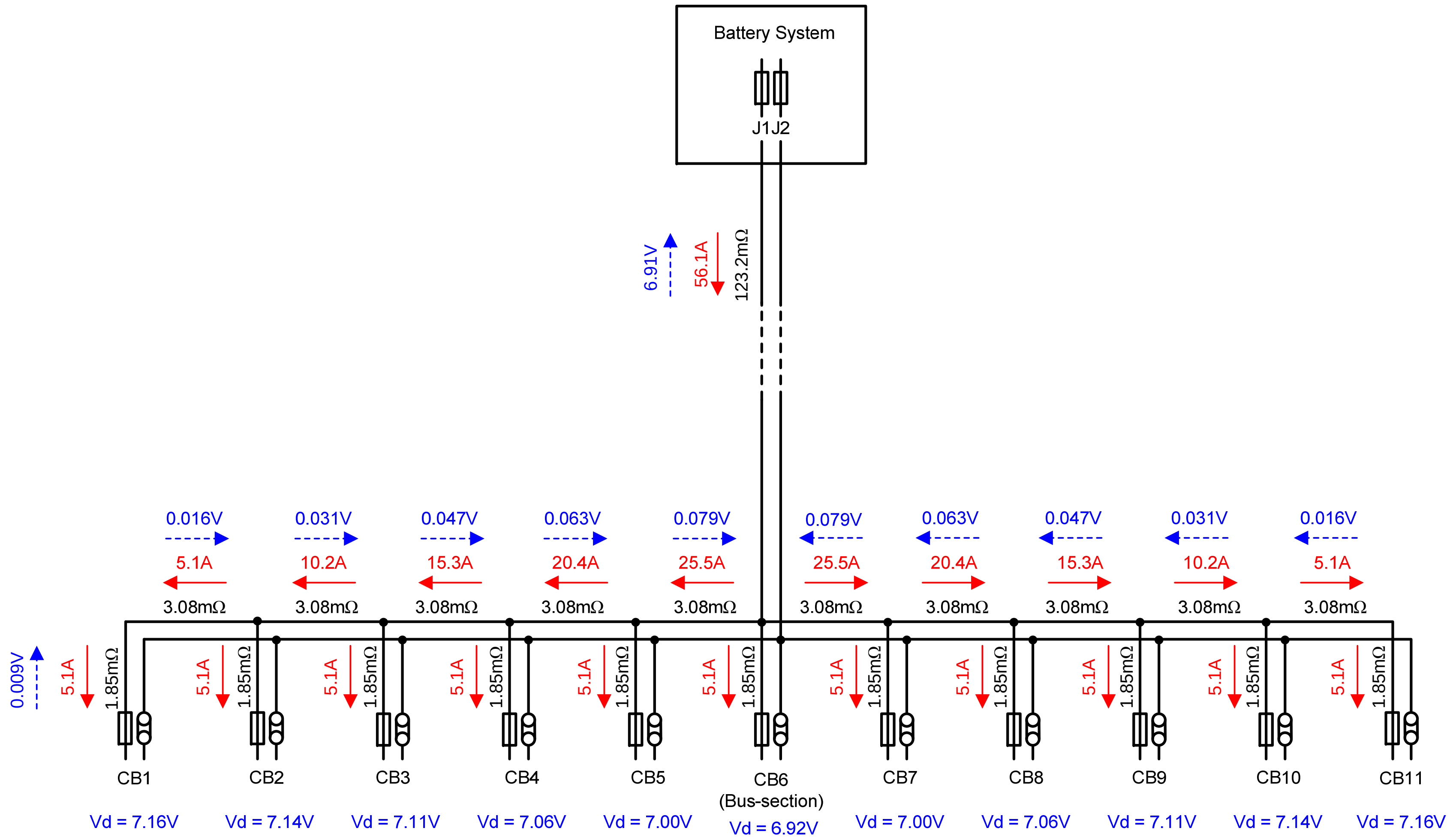


Figure D3.2 Voltage Drop Example - Voltage Drop on Secondary Wiring as CB1 Closes



Note, in this example the voltage drop is above the maximum acceptable voltage drop of 6V (for 110V systems).

Figure D3.3 Voltage Drop Example:- Voltage Drop on Secondary Wiring as all CBs Trip Simultaneously

APPENDIX D

SUPERSEDED DOCUMENTATION

This document supersedes ST:TP6K/2 which should now be withdrawn.

APPENDIX E

ANCILLARY DOCUMENTATION

EE SPEC : 25 (as amended) Substation 110V battery system specification.

EE SPEC : 24 (as amended) Substation 30V battery system specification.

APPENDIX F

POLICY IMPLEMENTATION

This Standard Technique shall be applied with immediate effect for new and substantially modified 110V and 30V battery systems and also where the capability of an existing battery system is re-assessed (i.e. where it is proposed to connect additional DC load to an existing battery system).

Managers shall ensure all staff involved in the design, specification, installation and replacement of substation plant, protection or battery systems are aware of the requirements of this document.

Where any difficulty is encountered in applying this ST the author should be notified who will determine whether a variation is appropriate.

APPENDIX G

POLICY IMPACT

This Standard Technique changes the method for determining the requirements for 110V and 30V battery systems. The following significant changes have been implemented:

a) The standby period for new 110V batteries has been increased from 8 hours to 24 hours to provide greater resilience. The 24 hour standby period for 30V systems remains unchanged.

   This 24 hour standby period shall be applied to all new and substantially modified 110V battery systems. It shall also be used where significant additional standing load is added the an existing battery system (e.g. where solid state relays are being installed or additional switchgear added).

b) The processes for selecting battery systems and for assessing existing batteries and chargers have been revised and simplified. A spreasheet has been developed which allows staff to easiliy check the capacity of batteries and chargers.

APPENDIX H

KEY WORDS

Battery, charger. VRLA, lead acid, NiCad. Planté