CERTIFICATION OF ENGINEERING CALCULATION

STATION AND UNIT NUMBER: Oconee Units 1, 2, & 3

TITLE OF CALCULATION: Battery Load and Voltage Profile for Station Blackout Event

CALCULATION NUMBER: OSC-4756

ORIGINAL CONSISTING OF:

PAGES 1 THROUGH

TOTAL ATTACHMENTS 1

TOTAL VOLUMES 1

TYPE I CALCULATION/ANALYSIS: YES □ NO □

TYPE I REVIEW FREQUENCY: 3 years

THESE ENGINEERING CALCULATIONS COVER QA CONDITION: 1 ITEMS. IN ACCORDANCE WITH ESTABLISHED PROCEDURES, THE QUALITY HAS BEEN ASSURED AND I CERTIFY THAT THE ABOVE CALCULATION HAS BEEN ORIGINATED, CHECKED OR APPROVED AS NOTED BELOW:

ORIGINATED BY: DATE: 6-18-92

CHECKED BY: DATE: 6-21-92

APPROVED BY: DATE: 6-24-92

ISSUED TO TECHNICAL SERVICES DIVISION:

RECEIVED BY TECHNICAL SERVICES DIVISION:

MICROFICHE ATTACHMENT LIST: □ Yes □ No SEE FORM 101.4

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1.0 PURPOSE

The purpose of this calculation is to show that the Oconee 125Vdc Instrumentation and Control Batteries can supply adequate voltage to loads during the coping duration of a Station Blackout Event.

2.0 ASSUMPTIONS

1. Loads are distributed equally between the panelboards, and loads on each unit are equal to Unit 1 loads.

2. Because of auctioneering diodes, total station loads are shared equally between batteries in service.

3. Inrush on an inverter due to a load starting is negligible.

4. Load growth factor, aging factor, and temperature factor are 1.1, 1.25, and 1.11 respectively, as required by IEEE Std 485-1983, with battery electrolyte temperature of 60°F.

5. Inverter loads are constant power loads, i.e. if voltage goes down, current goes up.

6. Non-inverter loads are static loads; if voltage goes down, current goes down.

7. Three units are operating at the time of the Station Blackout Event.

8. Four batteries with 58 cells each are operable at the time of the Station Blackout event.

3.0 REFERENCES

1. OSC-2429-Oconee Units 1, 2, and 3 Oconee 125V Control Battery Duty Cycle and Voltage Profile
2. OSC-2769-Oconee Nuclear Station, Unit 1 125VDC I&C Battery Load Test Report
3. Drawing 0-705-One-line 125Vdc Vital Instrumentation and Control System
5. IEEE Standard 450-1987
6. Oconee Station Blackout Response (in accordance with NUMARC 87-00)
7. Oconee Technical Specifications Section 3.7

4.0 SUMMARY OF RESULTS AND CONCLUSIONS

The battery output voltage will remain above 105V for the entire 4 hour SBO coping duration, with 4 batteries with 58 cells each operating.

5.0 DESIGN METHOD

The coping duration for a Station Blackout Event (SBO) at Oconee is four hours (See Reference 6). During this time, 125Vdc Vital Instrumentation and Control Power must be available to provide indication of pertinent plant parameters and control of switchgear. Existing dc calculations show that voltage will be adequate at all loads for a period of one hour if all loads are aligned to the system. Calculations exist showing voltage adequacy under some conditions to two hours. This calculation will document that adequate voltage will be available at least 4 hours after the loss of AC if the non-safety related inverters (1KI, 1KX, 1KU, 2KI, 2KX, 2KU, 3KI, 3KX, and 3KU) are removed from the safety-related 125Vdc distribution centers with-in 30 minutes or less after the loss of AC auxiliary power. This increase in discharge time is possible because the non-safety related inverters are a significant portion
of the total load on the safety-related DC system (47% of the 0-1 minute load and 59% of the after 1 minute load).

Technical Specifications allow 3 units to operate if five out of six batteries are operable. If a single failure of one battery occurs, the system is required to have enough capacity with four out of six batteries to supply adequate voltage.

In addition, a battery is assumed operable if 58 of 60 cells are operable. This calculation assumes that all four operable batteries have only 58 cells. Voltage is considered adequate if the battery voltage does not fall below 105V at any time within the discharge cycle. This corresponds to a minimum of 1.81 volts per cell for a 58 cell battery (See References 4 and 5).

The battery load profile is determined using the appropriate load profile from OSC-2429. This profile is modified to include the reduction in load 30 minutes into the event when the non-safety inverters are removed. This profile is used with the battery manufacturers data curves to determine the battery voltage at the beginning and end of each load period. These voltages are incorporated into a battery voltage curve.

6.0 LOAD PROFILE

The load profile for each battery when 4 batteries are operable with 58 cells per battery is calculated in OSC-2429. As stated in this calculation, each battery in the units with one battery operable will initially carry all three of the non-safety inverters for the unit \(I_{in}\), 1/4 of the total station safety-related inverter load \(I_{in}\), and 1/4 of the total station safety-related non-inverter load \(I_N\). All loads are expressed on a 125Vdc base.

The total non-safety related inverter load for each unit is \(I_{in} = 219\) amps (see OSC-2429). This load is removed from the batteries 30 minutes after the loss of AC auxiliary power. There are 12 safety-related inverters which pull 39 amps each. Each battery carries 3 of these inverters: \(I_N = 1/4 (12 \times 39\) amps\) = 3 \times 39 amps = 117 amps.

There are 12 safety-related panelboards which provide the safety-related, non-inverter load. Each battery will carry the equivalent load of three of these panelboards. The initial non-inverter load is \(I_{in}\); after one minute, the total non-inverter load is reduced to \(I_{in} = 123\) at 239 minutes the non-inverter load increases to \(I_{in} = 123\) to account for closing two breakers to restore AC power at the end of the four hour coping duration. \(I_N\) is based on a sequence of events in which the SK or SL breakers close when auxiliary AC power returns, followed by their spring charging motors running subsequent with the closing of the standby breakers in each unit. The SK and SL breakers, as well as all six of the S breakers, are fed from 1DIC and 1DID. If a Unit 1 battery is inoperable, then one battery could feed all of these breaker operations; 10 amps for each of the spring charging motors plus 6.7 amps for each breaker close, for a total of 60.2 amps. Restoration of AC auxiliary power through the standby bus causes the worst-case 125Vdc control power loading, since more breakers must close than if AC power is restored via the Startup breakers. In addition, the \(I_N\) calculated above assumes that the SK and S breakers are allowed to close automatically. If the breakers were to be placed in the "manual" mode prior the restoration of power, then only one breaker could close at one time, and the resulting control power load would be reduced.

\[I_{r1} = 135\ A\]
\[I_{r2} = 33\ A\]
\[I_{r3} = 93.2\ A\]

The worst case load profile for each battery, corrected for load growth (1.1), temperature (1.11), and aging (1.25), is shown in Figure 1.
The load profile in Figure 1 shows currents from test data corrected to a 125VDC base in OSC-2769. As mentioned in OSC-2429, tests were run on Units 1 and 2, and the results of the two tests were comparable. This profile is conservative in that it uses test data from Unit 1 loads. Unit 1 loads are slightly higher than Unit 2 and 3 loads. In addition, the load profile assumes certain 4KV breaker operations in the first minute which would not occur during a station blackout. Using the assumptions in Section 2.0 concerning constant power inverter and static non-inverter load currents, an equation can be written to model the total battery current as a function of the actual battery voltage.

\[
I(t) = I_{I}(t) \cdot \frac{V_{g}(t)}{125} + I_{T}(t) \cdot \frac{125}{V_{g}(t)}
\]

where \( I_{I}(t) = I_{Ins}(t) + I_{Is}(t) \)

\[
V_{g}(t) = \text{No. Cells} \times \frac{\text{Voltage}}{\text{Cell}} = 58 \times V_{c}(t)
\]

\[
I(t) = (0.464) \times V_{c}(t) \times I_{R}(t) + \frac{2.16 \times I_{T}(t)}{V_{c}(t)}
\]

where: 
- \( I(t) \) = Total Battery Current 
- \( I_{I}(t) \) = Total Inverter Current 
- \( I_{R}(t) \) = Total Non-Inverter Current 
- \( I_{Ins}(t) \) = Non-Safety Inverter Current 
- \( I_{Is}(t) \) = Safety Inverter Current 
- \( V_{g}(t) \) = Actual Battery Voltage 
- \( V_{c}(t) \) = Cell Voltage
7.0 **CALCULATION OF BATTERY VOLTAGE**

This calculation will use an iterative process, starting with \( V_0(t) = 2.06 \text{V} \), the open circuit voltage of a fully charged cell. This \( V_0(t) \) is inserted into the \( I(t) \) equation developed above to calculate \( I(t) \) for the given time. This \( I(t) \) is divided by the number of positive plates of the battery to find the amps per positive plate; this value can be used in the manufacturer's capacity curves to determine the ending cell voltage for this discharge rate for the given period of time. This new \( V_0(t) \) is then plugged back into the \( I(t) \) equation to determine a new \( I(t) \). The 125V Vital Instrumentation and control batteries are FTC-23 cells with 11 positive plates per cell. This iterative process continues until the new \( V_0(t) \) equals the \( V_0(t) \) value which was used to calculate it.

**For \( t = 0 \) to 1 minute**

- Assume \( V_0(t) = 2.06 \text{V} \)

\[
I(t) = I_R(t) \left( \frac{V_0(t)}{125} + I_R(t) \right) \frac{125}{V_0(t)}
\]

\[
I_R(t) = 334.3A + 178.6A = 512.9A
\]

\[
I_R = I_{R_1} = 206A
\]

\[
V_0(t) = \text{No. Cells} \times \frac{\text{Voltage}}{\text{Cell}} = 58 \times V_0(t)
\]

\[
I(t) = (0.464) \times 2.06 \text{V} \times 206A + \frac{2.16 \times 512.9A}{2.06 \text{V}} = 734.7A
\]

\[
\frac{734.6A}{11 \text{pp}} = 66.79A/\text{pp}
\]

Using the battery manufacturer's discharge curves, a discharge of 66.79A/\text{pp} for 1 minute yields a final voltage of 1.85 volts per cell.

- Assume \( V_0(t) = 1.85 \text{V} \)

\[
I(t) = I_R(t) \left( \frac{V_0(t)}{125} + I_R(t) \right) \frac{125}{V_0(t)}
\]

\[
I_R(t) = 334.3A + 178.6A = 512.9A
\]

\[
I_R = I_{R_1} = 206A
\]

\[
V_0(t) = \text{No. Cells} \times \frac{\text{Voltage}}{\text{Cell}} = 58 \times V_0(t)
\]

\[
I(t) = (0.464) \times 1.85 \text{V} \times 206A + \frac{2.16 \times 512.9A}{1.85 \text{V}} = 775.7A
\]

\[
\frac{775.7A}{11 \text{pp}} = 70.5A/\text{pp}
\]

From manufacturers curves, 70.5 A/\text{pp} for 1 minute yields 1.84 volts per cell.
Assume $V_c(t) = 1.84$ volts per cell.

\[ I(t) = (0.464) \times 1.84V \times 206A + \frac{2.16 \times 512.9A}{1.84V} = 778.0A \]

\[ \frac{778.0A}{11pp} = 70.7A/pp \]

70.7A/pp for 1 minute yields $V_c(t) = 1.84V$

The voltage per cell at the end of the first minute is 1.84V. This equates to a battery voltage of 106.72V.

$t = 1$ minute

Assume $V_c(t) = 1.84$ V

\[ I_{eq}(t) = 334.3A + 178.6A = 512.9A \]

\[ I_{eq} = I_{eq} = 50.4A \]

\[ I(t) = (0.464) \times 1.84V \times 50.4A + \frac{2.16 \times 512.9A}{1.84V} = 645.1A \]

\[ \frac{645.1A}{11pp} = 58.7A/pp \]

70.7A/pp x 1 minute = 70.7A-min/pp

At 1 minute, the battery has discharged 70.7 A·min/pp at a rate of 70.7 A/pp. The new estimated rate of discharge at 1+ minute is 58.7 A/pp. To find a cell voltage for the time immediately after the discharge rate decreases, an equivalent time to discharge the same amount of energy as discharged in 1 minute at 70.6 A/pp will be found. The energy discharged was 70.7A-min/pp. The equivalent time required to discharge that amount of energy at a rate of 58.7A/pp is 70.7A-min/pp + 58.7A/pp = 1.2 minutes. From the manufacturer's curve, 58.7A/pp for 1.2 minutes corresponds to a cell voltage of 1.86V.

Assume $V_c(t) = 1.86$ V

\[ I(t) = 639.1A = 58.1A/pp \]

70.7 A-min/pp is equivalent to 58.1 A/pp for 1.22 minutes

From the manufacturer's curves, $V_c(t) = 1.86V$

\[ V_B(t) = 107.9 V \]

$t = 30$ minutes

Assume $V_c(t) = 1.86V$

\[ I(t) = 58.1A/pp \]

The total accumulated discharge at 30 minutes is:

\[ 70.7 \text{ A-min/pp} + (58.1 \text{ A/pp})(29 \text{ min}) = 1755.6 \text{ A-min/pp} \]

1755.6A-min/pp is equivalent to 58.1A/pp for 30.22 minutes

From the manufacturer's curves, $V_c(t) = 1.84V$
Assume $V_c(t) = 1.84 \text{ V}$

$I(t) = 645.1 \text{ A} = 58.7 \text{ A/pp}$

The total accumulated discharge at 30 minutes is:

$70.7 \text{ A-min/pp} + (58.7 \text{ A/pp})(29 \text{ min}) = 1773 \text{ A-min/pp}$

1773 A-min/pp is equivalent to 58.7A/pp for 30.2 minutes.

From the manufacturer's curves, $V_c(t) = 1.84 \text{ V}$

$V_a(t) = 106.72 \text{ V}$

$t = 30^\circ \text{ minutes}$

Thirty minutes after the loss of Ac auxiliary power, the non-safety related inverters are disconnected from the DC Distribution Centers.

Assume $V_c(t) = 1.84 \text{ V}$

$I_{ac} = 0 \text{ A}$

$I_b = 178.6 \text{ A}$

$I_a = 50.4 \text{ A}$

$I(t) = 252.7 \text{ A} = 23.0 \text{ A/pp}$

The total accumulated discharge at 30 minutes is 1773 A-min/pp.

1773 A-min/pp is equivalent to 23.0 A/pp for 77.1 minutes.

From the manufacturer's curves, $V_c(t) = 1.94 \text{ V}$

$V_a(t) = 112.5 \text{ V}$

$t = 239^\circ \text{ minutes}$

Assume $V_c(t) = 1.94 \text{ V}$

$I(t) = 244.2 \text{ A} = 22.2 \text{ A/pp}$

The total accumulated discharge at 239 minutes is:

1773 A-min/pp + (22.2 A/pp)(239 min - 30 min) = 6412.8 A-min/pp

6412.8 A-min/pp is equivalent to 22.2A/pp for 288.9 minutes.

From the manufacturer's curves, $V_c(t) = 1.94 \text{ V}$

$V_a(t) = 112.5 \text{ V}$

Assume $V_c(t) = 1.88 \text{ V}$

$I(t) = 249.2 \text{ A} = 22.65 \text{ A/pp}$

The total accumulated discharge at 239 minutes is:

1773 A-min/pp + (22.65 A/pp)(209 min) = 6506.9 A-min/pp

6506.9 A-min/pp is equivalent to 22.65A/pp for 287.3 minutes.

From the manufacturer's curves, $V_c(t) = 1.88 \text{ V}$

$V_a(t) = 109.0 \text{ V}$
t = 239 minutes

Two hundred and thirty nine minutes into the event, certain switchgear is assumed to operate as described in Section 6.0.

- Assume $V_j(t) = 1.88$ V
  - $I_m = 0$ A
  - $I_b = 178.6$ A
  - $I_a = 142.2$ A
  
  $I(t) = 329.2$ A = 29.9 A/pp
  
  The total accumulated discharge at 239 minutes is:
  
  $1773$ A-min/pp + $(22.65$ A/pp$)(209$ min$) = 6506.9$ A-min/pp
  
  $6506.9$ A-min/pp is equivalent to $29.9$ A/pp for 217.6 minutes
  
  From the manufacturer's curves, $V_j(t) = 1.84$ V

- Assume $V_j(t) = 1.84$ V
  
  $I(t) = 331.1$ A = 30.1 A/pp
  
  $6506.9$ A-min/pp is equivalent to 30.1 A/pp for 216.2 minutes
  
  From the manufacturer's curves, $V_j(t) = 1.84$ V
  
  $V_a(t) = 106.72$ V

$t = 240$ minutes

- Assume $V_j(t) = 1.84$ V
  
  $I(t) = 331.1$ A = 30.1 A/pp
  
  The total accumulated discharge at 240 minutes is:
  
  $6506.9$ A-min/pp + $(30.1$ A/pp$)(1$ min$) = 6537$ A-min/pp
  
  $6537$ A-min/pp is equivalent to 30.1 A/pp for 217.2 minutes
  
  From the manufacturer's curves, $V_j(t) = 1.84$ V
  
  $V_a(t) = 106.72$ V

The battery voltage profile for the entire station blackout event is shown in Figure 2.
Calcium Flat Plate

Type FTC
Long Duration

- Lowest maintenance—lowest water loss, lowest maintenance costs
- Highest 1 minute rates
- Flat-plate construction—calcium alloy grids
- For floating applications where high ambient temperatures are not probable
- 20 year life expectancy
- An extra large electrolyte reservoir, in conjunction with tailored plate design,

maximizes performance for discharges of more than two hours in duration while maintaining excellent short duration-high current performance. This design provides an extremely attractive, less expensive alternative for many switchgear-type applications as well as the traditional long duration requirements characteristic of communications applications.

SPECIFICATIONS

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<th>PLATE DIMENSIONS</th>
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<th>WIDTH</th>
<th>THICKNESS</th>
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<td>12.1 in/307 mm</td>
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<td>14.4 in/366 mm</td>
<td>12.1 in/307 mm</td>
<td>0.24 in/6.1 mm</td>
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| SEDIMENT SPACE: | 1.0 in/25.4 mm |
| ELECTROLYTE OVER PLATES: | 2.9 in/73.7 mm |
| CONTAINER: | Styrene Acrylonitrile Copolymer |
| COVER: | Styrene Butadiene |
| SEPARATORS: | Microporous rubber |
| RETAINERS: | "Vitrex"—glass fiber |
| POST TYPE: | Double posts |
| POST SEAL TYPE: | Axial Compression with Machined Post |
| PLATE SUSPENSION TYPE— | |
| POSITIVE: | Ledge hung |
| NEGATIVE: | Ledge hung |
| ELECTROLYTE WITHDRAWAL TUBE: | One per cell |
| VENT TYPE: | Flame arrester, fused alumina |
| FLOAT VOLTAGE— | |
| ACCEPTABLE RANGE: | 2.17—2.26 VPC |
| RECOMMENDED: | 2.25 VPC |
| SPECIFIC GRAVITY: | 1.215 (1.250 and 1.300 available on request) |
| BOLT CONNECTORS: | Stainless steel, standard English measure hex-head |
| INTERCELL CONNECTORS: | Lead-plated copper |
## Capacities - Dimensions - Weights

### Average Cell Performance Data*

Discharge rates in amperes.  
1.215 SP. GR. ELECTROLYTE AT 77° (25°C), INCLUDING CELL CONNECTORS

### To 1.75 VPC Final

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*Suffix Number Indicates Total Plates Per Cell

*Average values and are subject to IEEE-485
AVERAGE CAPACITY OF MEAN-SIZE CELLS INCLUDING CONNECTORS

Type: FTC
Temp. 77°F (25°C)
Date: 12/76
Sp. Gr. 1.215

Amperes per Positive

Volts per Cell

Capacity of Individual Batteries

Capacity of 3-Cell Batteries

Initial Voltage

Final Voltage

Percent of Time to Final Voltage

20%
40%
60%
80%
90%

1.8
2.0
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0

AMPERES PER POSITIVE

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
### Standard-Rack Selection Guide for “FTC” Cells*

**CAUTION:** Additional length may be required for seismic and high seismic racks.

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<th>CELL SIZE</th>
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<th>2 STEP</th>
<th>2 STEP/TIER</th>
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</table>

This rack selection guide is applicable for standard racks with or without shock-protecting equipment. For additional information about standard racks, see Catalog Sections 55.10, 55.22 through 55.28. For information about shock-protecting equipment, see seismic and high seismic racks for “FTC” Series Cells, see Sections, 55.01, 55.45, 55.60, 55.65, and 55.80.

### Accessories

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<td>ARRESTOR (Supplied With Each Cell)</td>
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For complete information about these and all other accessories, see Catalog Section 55.91.

---

**Note:**

All inter-cell, inter-tier, inter-step, end-to-end inter-rack, back-to-back inter-rack connectors, terminal lugs, and terminal plates are included with every battery. Across-aisle inter-rack connectors are not included.
ATTACHMENT IV

ROOM HEATUP CALCULATION FOR STATION BLACKOUT EVENT