Auxiliary DC Power Supply for Distribution Substations

Presented at INFOBATT 2005 by:
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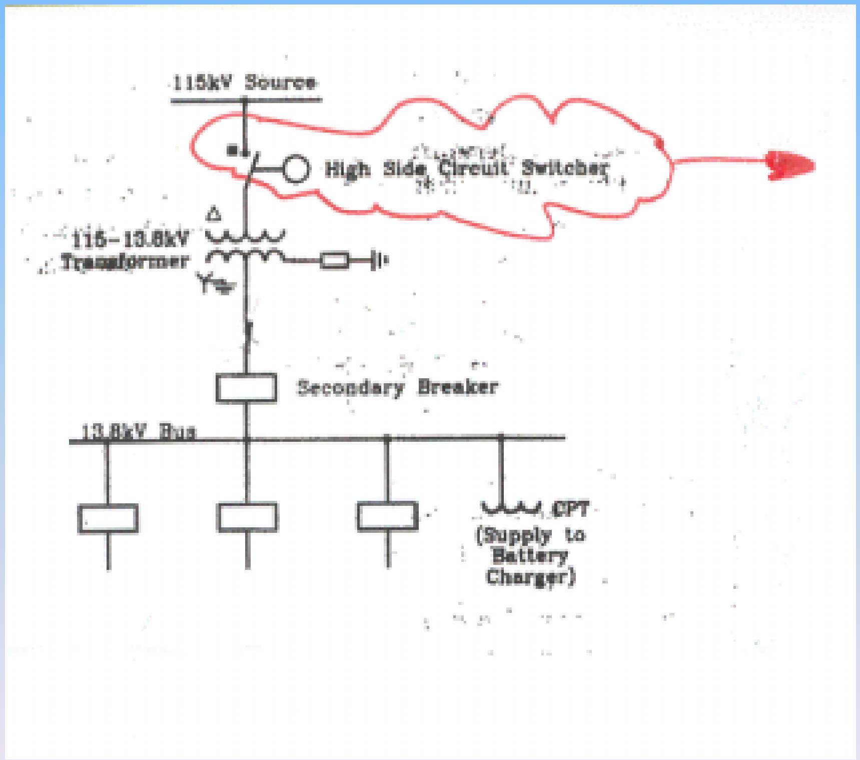
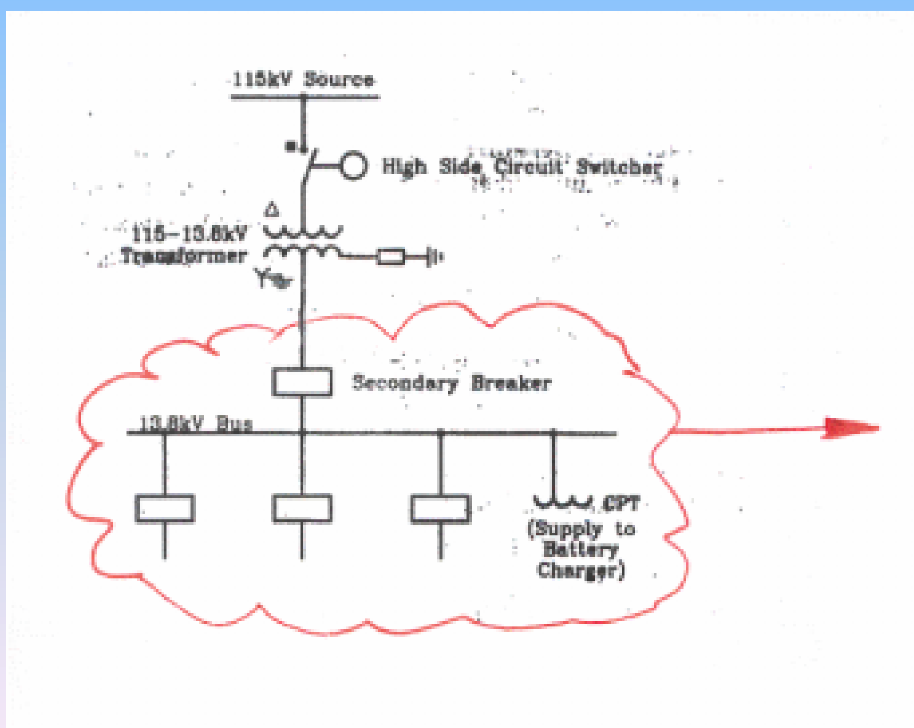
Application of Auxiliary DC Power Supply in Distribution Substations

- 115kV Circuit Switcher



Application of Auxiliary DC Power Supply in Distribution Substations

- Metal-Clad Switchgear



Distribution Substation with Circuit Switcher

- U-70 DS standard
- Neither equipment shelter nor masonry building
- Outdoor enclosure for 48Vdc power supply - column mounted

Distribution Substation with Circuit Switcher

- U-90 DS standard
- R-20 Insulated equipment shelter
- Economical room air-conditioning available
- Compact 19”-rack for 48Vdc power supply

Distribution Substation with Outdoor Metal-Clad Switchgear

- No wall thermal insulation
- No air-conditioning
- Heat gain from switchgear and sun
- Unfavorable conditions for batteries
- Space limitation
- End of life approaching

Distribution Substation with Indoor Metal-Clad Switchgear

- Masonry building
- No air-conditioning
- Heat gain from switchgear

What is our present practice?

In last few years Hydro One acquired few local municipality utilities in Ontario.

What is our present practice?

- AGM Type VRLA Battery

What is our present practice?

- Flooded Nickel-Cadmium Battery

What is our present practice?

- Car Battery

What is our present practice?

- Flooded Lead-Acid Battery

What is our present practice?

- Flooded Lead-Acid Battery Replaced with Car Battery

What is our present practice?

- GEL Type Lead-Acid VRLA Battery

Requirements for Auxiliary DC Power Supply in Distribution Substations

- Minimum 8 hours low-rate current discharge
- Momentary high-current discharge
- Extreme ambient temperatures
- Limited space available
- Reliable DC power supply
- Reduced construction lead time and cost
- Reduced maintenance cost
- Low overall life-cycle cost
- Safe and environmentally friendly

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Integrated Auxiliary DC Power Supply for Distribution Substation

- Selecting the Right Battery for Distribution Station
- Specifying Appropriate Charger for Selected Battery
- Enclosure Thermal Management and Gas Evacuation

What is the Right Stationary Battery for Application in Distribution Substations?

- Flooded Lead-Acid
- Flooded Nickel-Cadmium
- AGM Type Lead-Acid VRLA
- GEL Type Lead-Acid VRLA
- Nickel-Cadmium VRLA

Flooded Lead-Acid Battery

- The most reliable and proven battery technology for stationary battery application in transmission substations (no extreme temperatures)
- They are expensive, but you get what you pay for
- Need maintenance - without proactive maintenance there is no good battery performance
- Need ventilated and temperature controlled room
- Need spill containment, occupy large footprint
- Not the best choice for distribution substations

Flooded Nickel-Cadmium Battery

- An excellent battery for floating, cycling and engine starting applications (different plate thickness), especially in extreme temperature environments
- ENVIROMENTAL CONCERN regarding cadmium toxicity
- High initial investment COST, higher disposal cost and high life-cycle cost if used in controlled ambient or moderate climate
- Mostly used in extreme temperature environments where Ni-Cd batteries has advantages and lower life-cycle cost comparing with lead acid batteries

Lead-Acid VRLA Battery Technology

- 2Vdc - cell, 20 years designed life (???), lead-calcium plates, 200-2000Ah, AGM or GEL
- 12Vdc - monoblock, 10 years designed life, lead-calcium, thin or thick plates design, 50-600Ah, AGM or GEL
- 12Vdc – monoblock, 12+ years design life, lead-tin, thin plate technology, up to 100Ah, AGM

Lead-Acid VRLA Battery Advantages

- Low initial investment cost
- No need for spill containment
- Smaller floor requirements
- Higher power density
- No need for separate room
- Safer for maintenance

Lead-Acid VRLA Battery Disadvantages

- Does not meet specified life expectancy because technology limitations and normal and unique failure modes (positive grid corrosion, low negative grid polarization, thermal run-away, dry-out)
- Require temperature controlled environment
- Very sensitive to improper charging
- Require extensive maintenance and monitoring
- A permanent topic on battery conferences
- Philadelphia Scientific (conducts research on VRLA batteries) http://www.phlsci.com/VRLA_Catalyst/Technical_Papers/technical_papers.html

Pure Lead & Pure Lead-Tin VRLA Battery

- Plante used pure lead when he developed the world's first rechargeable lead acid cell in 1859
- Corrosion of positive grid / grid growth limits battery life, if no other reason cause failure before
- Pure lead is the least susceptible metal to corrosion in lead-acid battery, but has some other undesirable effects
- A small addition of tin to pure lead improves deep-discharge performance, creep resistance of grid material, stabilize active material, improve contact between grid and active material

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Pure Lead & Pure Lead-Tin VRLA Battery

- In early 1970s Gates Corporation developed and patented cylindrical valve regulated cells with punched grids employing pure lead
- In early 1990s Gates Corporation (later acquired by Hawker) launched pure lead and pure lead-tin monoblock VRLA batteries with flat plates
- Only two manufacturers in the world: EnerSys (USA) [former Hawker] and HBL NIFE (India)
- The manufacturers claim advantages of pure lead-tin, thin plate VRLA battery technology over lead-calcium counterparts

If Pure Lead is so Good, why are Alloys so Common?

- Pure lead is difficult to handle on manufacturing line, and not enough strong to support active material
- Manufacturers add alloying elements to pure lead for manufacturing and technical convenience, and to improve some battery electrical performances
- Additives: calcium, antimony, selenium, tin, silver, gold, copper, aluminum, cadmium, strontium
- Alloying elements increase the grid corrosion rate which necessitates the use of thicker grids for obtaining longer life, but sacrificing the energy density and high rate performance of the battery

Why Tin, Why not Calcium?

- Calcium (<0.4%) is being added to pure lead to increase mechanical strength of grid material for manufacturing convenience. But, disadvantage or lead-calcium alloy is increased positive grid corrosion and grid growth.
- Tin (<0.8%) is being added to pure lead to improve creep resistance of grid material, stabilize active material, improve contact between grid and active material, and to improve deep-discharge performance, but it is less susceptible to grid corrosion than calcium.

Features and Benefits of Pure Lead-Tin Thin Plate VRLA Battery

- Pure lead-tin grid alloy: reduced corrosion rate of positive plate - benefits with longer float service life
- More thin plates: increased plate surface, higher active material utilization, higher compression and reduced internal impedance - benefits with high-current discharge capability, cycling capability, deep discharge recovery capability, quick recharge capability, better performance at extreme low temperatures

Lead-Tin Thin Plate versus Lead-Calcium Thick Plate Technology

Advantages of Lead-Tin Thin Plate battery technology:

- Lower internal resistance - better high-rate pulse discharge capability, better deep discharge recovery capability, better discharge capability at lower temperatures, better fast recharge capability, higher gravimetric and volumetric power density
- Reduced positive grid corrosion rate - longer float life
- Lower negative plate self-discharge – longer shelf life
- Better resistance to thermal run-away in uncontrolled environments (per presentation at BATCONN 2005)
- Higher pack compression - higher cycling capability

Comparison of Lead-Calcium and Lead-Tin VRLA Batteries - Discharge Profile at Different Temperatures

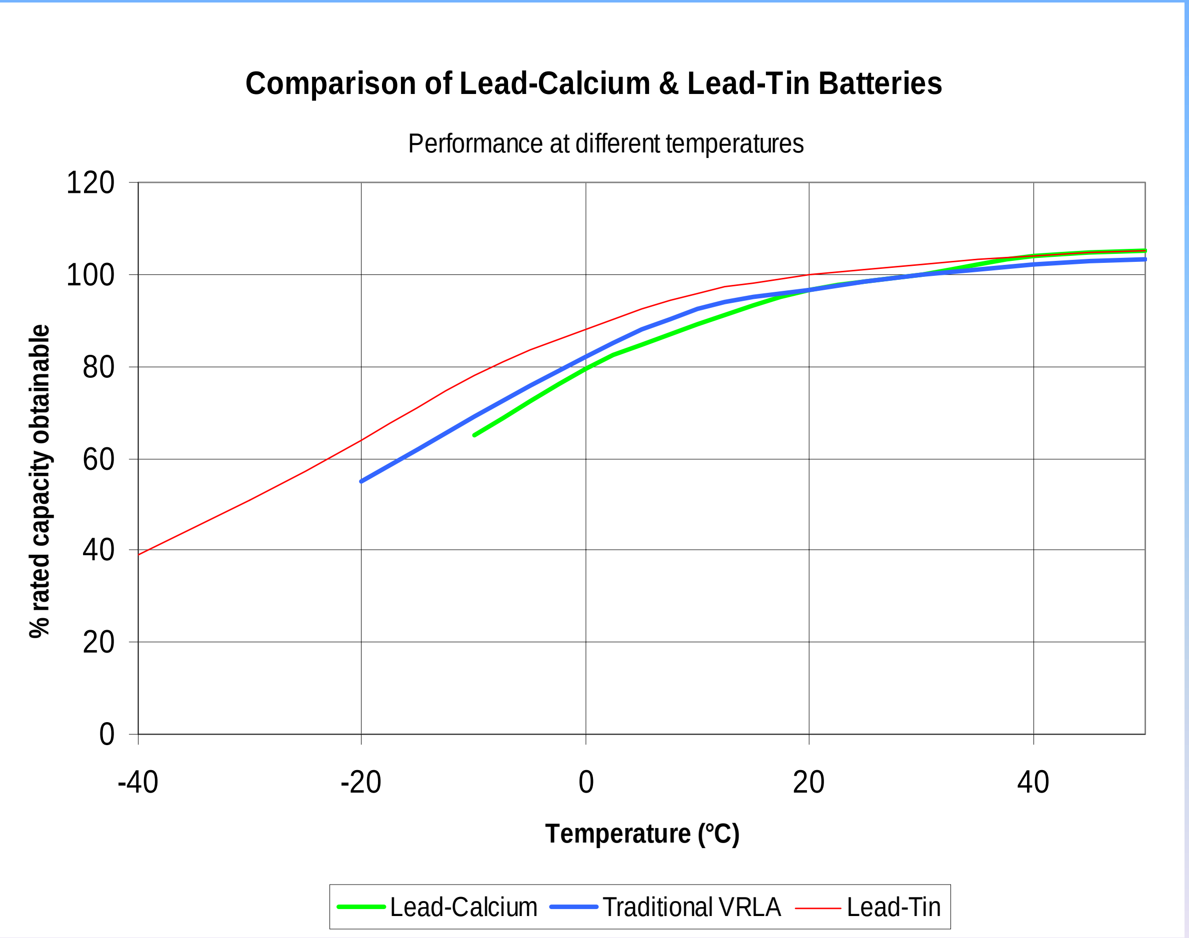

Chart Provided by HBL NIFE Power Systems Limited

Who are Users of Pure Lead VRLA Batteries in USA & Canada ?

- Manufacturer EnerSys could not provide a user's reference list as battery sales goes through distribution centers and value-added centers
- EnerSys claims that manufacture pure lead-tin thin plate VRLA batteries for military combat and tactical vehicles, military and civil aircrafts, ships and submarines, defense installations, telecom, UPS and railway industry, electrical utilities...
- Distribution Utilities: Circuit Recloser Controller (Schweitzer) installed in outdoor enclosure

Typical Battery Duty Cycle for Switchgear Application

Table No. 3 Typical 125Vdc Battery Duty Cycle for Switchgear Application

Load	Current	Duration
Load No.1	2A	480 minutes
Load No. 2	80A	1 minute

Notes:

- Motor inrush current is 6-8 times steady state current.
- Feeder breakers usually have no under-voltage relay.
- All continuous loads are assumed to be 2A.
- All breaker trip and close currents and motor charging current are represented as motor inrush current in duration of 1 minute.

Sizing Led-Tin Battery for Typical Switchgear Application

Table No. 5 Battery Sizing Worksheet per IEEE Std. 485 (for Duty Cycle from Table No. 3)

(1) Period	(2) Load [A]	(3) Change in Load [A]	(4) Duration of Period [min]	(5) Time to End of Section [min]	(6) Cap at T min rate K factor	(7) Reqd sec size 3*6 (Ah)
1	A1=2	A1-0=2	M1=480	T=M1+M2=481	9.20	18.4
2	A2=80	A2-A1=78	M2=1	T=M2=1	0.157	12.25
Total [Ah]						30.65
Applying Ageing Factor 1.25 30.65=					1.25 x	38.31
Applying Temperature Correction Factor for -10°C 38.31=					1.4 x	53.62
Applying Design Margin 1.1 1.1x53.62=						58.99
Selected Pure Lead-tin Thin Plate VRLA Battery Capacity [Ah]						**70.00**

Typical Battery Duty Cycle for Circuit Switcher

Table No. 8 Typical 48Vdc Battery Duty Cycle for 115kV Circuit Switcher (U-90 Distr. Stn.)

Load	Current [A]	Duration [min]
Load No.1	1	480
Load No. 2	40	1

Notes:

- All continuous loads are assumed to be 1A (actual load is probable less than 1A).
- Motor inrush current is not taken in battery duty cycle as 1 minute load. Circuit switcher manufacturer's recommendation is selected battery must have minimum 75A, 1 minute discharge rating at 1.75 V/cell, that takes in account motor inrush current.
- All motor, trip and close operations are represented with motor running current in duration of 1 minute.

Sizing Lead-Tin Battery for Typical Circuit Switcher Application

Table No. 9 Battery Sizing Worksheet per IEEE Std. 485 (for Duty Cycle from Table No. 8)

(1) Period	(2) Load [A]	(3) Change in Load [A]	(4) Duration of Period [min]	(5) Time to End of Section [min]	(6) Cap at T min rate K factor	(7) Reqd sec size 3*6 (Ah)
1	A1=1	A1-0=1	M1=480	T=M1+M2=481	9.20	9.2
2	A2=40	A2-A1=39	M2=1	T=M2=1	0.157	6.12
Total [Ah]						15.32
Applying Ageing Factor 1.25					1.25 x 15.32=	19.15
Applying Temperature Correction Factor for -10 °C					1.4 x 19.15=	26.81
Applying Design Margin 1.1					1.1x26.81=	29.49
Selected Pure Lead-Tin Thin Plate VRLA Battery Capacity [Ah]						**40.00**
Note: Selected battery must have minimum 75A, 1 minute discharge rating at 1.75 V/cell						

Selected Lead-Tin Thin Plate VRLA Batteries for Application in Distribution Stations

Cat Id.	Description	Manufacturer & Model	
		EnerSys Inc.	HBL NIFE Ltd.
49064	Pure Lead-Tin, Thin Plate, 40Ah, 12Vdc monoblock VRLA battery	Genesis XE40	PLT 40-12
49065	Pure Lead-Tin, Thin Plate, 70Ah, 12Vdc monoblock VRLA battery	Genesis XE70	PLT 70-12

http://www.enersysreservepower.com/documents/US-GPL-AM-002_0605.pdf
http://216.237.122.153/Brochures/HBL%20PLT%20Technical%20Manual.pdf



Battery Charger Highlights

Proper charging is one of the most important factors to consider when using lead-acid VRLA batteries

- Standards CSA C22.2 No.107.2-M89 and NEMA PE5
- Constant voltage battery charger
- Temperature compensated DC output voltage
- Filtered and regulated DC output voltage
- Low volts disconnect
- Functional without battery
- Ground fault detection
- Standard set of alarms

Selected Battery Chargers for Application in Distr. Stations

DC Output Voltage [V]	DC Output Current [A]	Application
55	6	Circuit Switcher
55	12	Switchgear
136	12	Switchgear

Integrated Auxiliary Power Supply System for Distribution Substations - Highlights

Design Considerations:

- Space Requirements
- Ambient Temperature
- Thermal Management of Battery Compartment
- Hydrogen Gas Evacuation

Installation Options:

- Outdoor Cabinet
- Indoor Cabinet or Rack
- Indoor, 19” relay rack

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Integrated Auxiliary Power Supply System for Distribution Substations - Options

Table 1. Integrated auxiliary DC power supply systems (battery, charger, rack/enclosure) for distribution stations

Type	Cat.Id.	System Voltage [Vdc]	Battery Capacity [Ah]	Charger Current [Adc]	Battery & Charger Rack or Enclosure	Battery & Charger Installation	Application
A		48	70	12	Pad mounted outdoor enclosure	Outdoor	MV metal-clad switchgear installed in non-insulated outdoor metal enclosure (limited space).
B		48	70	12	Stand-alone indoor enclosure	Indoor	MV metal-clad switchgear installed in non-heated masonry or prefabricated building (available space for battery and charger).
C		48	70	12	Battery rack + wall mounted charger indoor enclosure	Indoor	MV metal-clad switchgear installed in heated masonry or prefabricated building (available space for battery and charger).
D		48	40	6	Steel column mounted outdoor enclosure	Outdoor	115kV circuit switcher and distribution transformer protection application. There is no building. Aux. DC system installed in steel column mounted outdoor enclosure
E		48	40	6	19” relay rack	Indoor	115kV circuit switcher and distribution transformer protection application. Aux. DC system installed in heated masonry or prefabricated building (available space for battery and charger)
F		125	70	12	Pad mounted outdoor enclosure	Outdoor	MV metal-clad switchgear installed in non-insulated outdoor metal enclosure (limited space).
G		125	70	12	Stand-alone indoor enclosure	Indoor	MV metal-clad switchgear installed in non-heated masonry or prefabricated building (available space for battery and charger).
H		125	70	12	Battery rack + wall mounted charger indoor enclosure	Indoor	MV metal-clad switchgear installed in heated masonry or prefabricated building (available space for battery and charger).

The system integrator shall deliver completely assembled, wired and tested auxiliary DC system. The batteries could be shipped separately.

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Ontario Ambient Temperatures

Number of Days with Maximum Temperature per Year (1971-2000)

Temperature	Niagara Falls	Windsor	Toronto	Belleville	Ottawa	North Bay	Timmins	Kapuskasing	Fort Frances	Moosonee
<= 0 °C	53.1	46.1	57.2	58.3	81.3	102.4	116.7	121.6	109.5	132.5
> 0 °C	312.1	319.1	308.0	307.0	284.0	262.8	248.5	243.7	255.8	232.8
> 10 °C	213.1	223.4	207.5	203.8	195.8	179.1	167.8	163.5	180.2	146.6
> 20 °C	123.8	135.9	118.0	114.1	112.3	86.9	85.7	81.5	99.3	61.7
> 30 °C	12.8	20.7	12.6	6.1	11.3	1.6	6.4	5.7	6.9	4.8
> 35 °C	0.20	1.0	0.54	0.03	0.16	0.03	0.24	0.14	0.16	0.04

Number of Days with Minimum Temperature per Year (1971-2000)

Temperature	Niagara Falls	Windsor	Toronto	Belleville	Ottawa	North Bay	Timmins	Kapuskasing	Fort Frances	Moosonee
> 0 °C	236.4	242.5	219.1	225.8	206.0	185.3	154.8	150.9	169.4	135.1
<= 2 °C	153.9	150.1	175.6	164.8	182.0	201.4	233.9	235.9	218.1	255.0
<= 0 °C	128.9	122.8	146.2	139.5	159.2	180.0	210.5	214.4	195.9	230.2
< -2 °C	95.1	93.4	114.3	107.4	132.2	153.5	180.3	185.0	166.8	194.5
< -10 °C	29.9	28.7	45.4	47.9	71.0	89.2	114.6	119.9	96.3	131.0
< -20 °C	1.1	1.6	5.2	8.5	18.4	33.8	63.7	70.4	51.3	84.9
< - 30 °C	0.0	0.0	0.10	0.37	0.50	3.4	17.4	21.9	18.3	33.5

Source of information: Environment Canada,
http://www.ec.gc.ca/

Outdoor Enclosure Highlights

- Designed for weather conditions in Ontario
- Separate charger and battery compartment
- NEMA 3R enclosure - aluminum rigid construction
- No air-conditioning specified
- Thermostatically controlled exhaust fan
- Thermostatically controlled space heater
- Thermal Insulation R-14 - 2” thick polyisocyanurate foam sheating board
- Painted in semi-gloss white colour
- Hydrogen gas evacuation

THE END

RECOMMENDED BOOK!

The winner shall be announced by 2015!