Substation Engineering

Batteries and DC Systems (Part 1 of 2)

Milav Dabgar

Batteries and DC Systems (Part 1 of 2)

- Substation Engineering (DI04009011)
- Unit 5: Auxiliary Systems and Routine Operations
- Lecture 21: Batteries and DC Systems

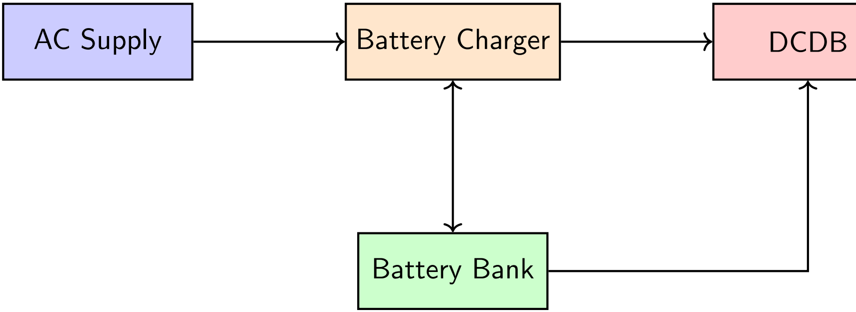
Agenda

- Importance of DC Systems in Substations
- Components of a Substation DC System
- Types of Batteries (Lead-Acid vs. Ni-Cd)
- Battery Terminology and Ratings
- Substation DC Load Profiles
- Basics of Battery Sizing

Importance of DC Systems in Substations

- Provides independent, reliable power for critical substation equipment
- Operates protective relays, control circuits, and automation systems
- Powers the trip and close coils of high-voltage circuit breakers
- Maintains operation during complete AC station power failure (blackout)
- Emergency lighting and communication systems rely on the DC bank

Components of a Substation DC System



- AC Auxiliary Supply (input from Station Service Transformer)
- Battery Charger (Rectifier): Converts AC to DC
- Battery Bank: Stores DC energy
- DC Distribution Board (DCDB): Distributes DC power to various loads
- Protection Devices: Fuses and DC Miniature Circuit Breakers (MCBs)

Types of Batteries Used in Substations

Feature	Vented Lead-Acid (VLA)	Valve Regulated Lead-Acid (VRLA)	Nickel-Cadmium (Ni-Cd)
Electrolyte	Liquid Sulfuric Acid	Gelled/Absorbed Acid	Potassium Hydroxide (Alkaline)
Maintenance	High (add water)	Low	Moderate
Life Expectancy	15-20 years	5-10 years	20+ years
Cost	Moderate	Low	High

Vented Lead-Acid (VLA) Batteries

- Composed of lead dioxide (positive) and sponge lead (negative) plates
- Submerged in an electrolyte of dilute sulfuric acid
- Nominal voltage per cell is 2.0V
- Transparent cases allow visual inspection of plates and electrolyte levels
- Requires periodic topping up with distilled water due to outgassing

Nickel-Cadmium (Ni-Cd) Batteries

- Uses nickel oxide hydroxide (positive) and metallic cadmium (negative)
- Alkaline electrolyte (Potassium Hydroxide) does not participate directly in the chemical reaction
- Nominal voltage per cell is 1.2V
- Highly resistant to temperature extremes and deep discharging
- Does not suffer from sudden death syndrome like some lead-acid types

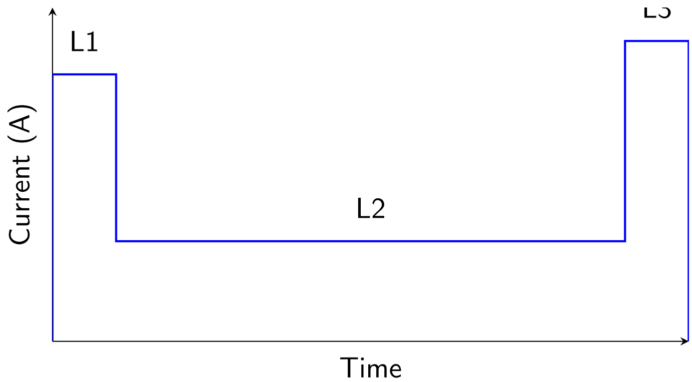
Battery Terminology: Ampere-Hour (Ah) Capacity

- Capacity is measured in Ampere-Hours (Ah) at a specific discharge rate
- Standard rating for substation batteries is usually the 8-hour rate (C8)
- Example: A 400 Ah battery can supply 50 Amps for 8 hours (50A x 8h = 400Ah)
- Capacity varies with discharge time; higher discharge currents yield lower effective capacity
- Temperature affects capacity: rated at 25 degrees Celsius (77 degrees Fahrenheit)

Battery Terminology: C-Rate and Depth of Discharge

- C-Rate: A measure of the rate at which a battery is discharged relative to its maximum capacity
- 1C rate means discharge in 1 hour; 0.1C rate means discharge in 10 hours
- Depth of Discharge (DoD): The percentage of battery capacity that has been discharged
- Example: Discharging 100 Ah from a 400 Ah battery equals 25% DoD
- End of Discharge Voltage (EODV): Minimum allowable voltage before permanent damage occurs (typically 1.75V for Lead-Acid)

Substation DC Load Profile



Classification of DC Loads

Load Type	Description	Duration	Example
Continuous	Always energized	Entire duty cycle	Relays, SCADA RTU, indicators
Non-Continuous	Energized for a specific time	Minutes to hours	Emergency lighting, lube pumps
Momentary	Instantaneous high current	Fraction of a second	Breaker trip/close coils, motor charging springs

Battery Sizing Considerations (IEEE 485)

- Determine the duty cycle based on utility standards (e.g., 4 or 8 hours of backup)
- Calculate continuous, non-continuous, and momentary loads
- Apply Design Margin (typically 10-15%) for future growth
- Apply Aging Factor (typically 25% extra capacity so it meets load at end of life)
- Apply Temperature Correction Factor for lowest expected ambient temperature

The Battery Charger

- Usually a solid-state thyristor (SCR) based rectifier
- Sized to carry the continuous DC load PLUS recharge a fully depleted battery within a specified time (e.g., 12 hours)
- Features two primary modes: Float Charge and Boost (Equalize) Charge
- Equipped with alarms for AC fail, DC under/over voltage, and charger failure
- Dual charger schemes (redundant) are used in critical EHV substations

Summary

- DC systems provide uninterrupted power to critical protection and control equipment
- The system consists of the AC source, charger, battery bank, and DCDB
- Vented Lead-Acid and Ni-Cd are the primary battery chemistries used
- Battery sizing requires understanding continuous, non-continuous, and momentary loads
- IEEE 485 standard dictates applying margins for aging, temperature, and future design

Preview of Next Lecture

- Float vs. Boost Charging operations in detail
- Battery maintenance, inspection, and testing procedures
- Measuring specific gravity and using a hydrometer
- DC system ground faults and detection methods
- Safety precautions in the battery room