

Load Balance Algorithm

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# 1 Introduction

{{ company\_name }} Project: {{ project\_name }} Client: {{ client\_name }} Location: {{ site\_location }} Date: {{ report\_date }}

System Capacity: {{ system\_capacity }} Number of Panels: {{ panel\_count }} Annual Generation: {{ annual\_generation }} Annual Savings: {{ annual\_savings }} Payback Period: {{ payback\_period }}

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The algorithm logically prioritizes different types of generation with respect to emission while respecting the physical and economic constraints of each technology. The real-world operation of an electrical grid, must balance supply and demand every hour while minimizing costs and maintaining reliability.

# Load Balance Calculation Process

## Overview

The load balance calculation simulates how an electricity grid operates hour by hour throughout a full year (8,760 hours), matching electricity supply from various technologies to meet the demand (load).

This simulation can provide an insight into how different combinations of technologies could perform and the emissions, costs and reliability implications of different combinations and ratios.

## Hour-by-Hour Process

### Setup Phase

Before processing each hour, the system:

* Gets the electricity demand (load) for that hour.
* Applies parasitic losses to any energy storage systems (batteries lose a small amount of stored energy each hour).
* Resets tracking for each technology contribution.

### Phase 1: Must-Run Generation

**First, handles generators that must always run at a minimum level:**

* Some power plants (e.g. large thermal plants) have minimum operating requirements otherwise known as baseload.
* These "must-run" generators operate at their minimum capacity regardless of whether that electricity is needed and therefore will bid into the wholesale market for this capacity irrespective of price.
* This minimum generation is subtracted from the total demand.
* If this minimum generation exceeds the current demand, the excess becomes "curtailed" (wasted) energy.

**Phase 2: Merit Order Dispatch**

**Next, meet remaining demand using technologies in priority order:**

The system works through each technology in "merit order" (typically cheapest to most expensive):

**Non-Dispatchable Renewables (Solar/Wind):**

* Available generation: The amount of electricity these can produce depends on weather conditions (sun/wind)
* Priority usage: If there's still demand, use as much renewable energy as available
* Curtailment: If there's no remaining demand, this renewable energy gets "curtailed" (wasted)

**Storage Systems (Batteries):**

* Discharging: If there's stored energy and remaining demand, batteries discharge to help meet the load
* Operating rules: Some storage systems have minimum runtime requirements or warm-up penalties
* Efficiency losses: Converting stored energy back to electricity isn't 100% efficient

**Dispatchable Generators (Power Plants):**

* Minimum generators: Those that already ran at minimum can now increase output up to their maximum capacity if more power is needed
* Other generators: Regular power plants turn on and ramp up as needed

### Phase 3: Handle Excess Energy

**Finally, deal with any leftover electricity:**

* If there's excess renewable energy that was curtailed, try to store it in batteries
* Charging efficiency: Storing energy in batteries involves some efficiency losses
* Storage limits: Batteries can only charge at certain rates and have maximum capacity limits

**End of Hour Accounting:**

For each hour, the system records:

* Shortfall: Any demand that couldn't be met (blackouts)
* Surplus: Any excess generation that couldn't be used or stored
* Curtailment: Renewable energy that was available but had to be wasted
* Generation by technology: How much each power source contributed
* Cost
* Emissions

### Key Principles

**Economic Merit Order:**

Technologies generally operate in order of cost (cheapest first), ensuring the most economical way to meet demand.

**Physical Constraints:**

The simulation respects real-world limitations:

* Storage systems have capacity, charge/discharge rates, and efficiency losses
* Power plants have minimum/maximum output levels and startup requirements
* Renewable energy depends on weather conditions

**Grid Reliability:**

The process ensures grid stability by:

* Always meeting must-run requirements first
* Properly handling storage system operational constraints
* Tracking when demand cannot be met (shortfall)

### Output

After processing all 8,760 hours, the system provides:

* **Summary statistics**: Total generation, costs, emissions, reliability metrics
* **Detailed hourly data:** Generation profiles, storage levels, curtailment patterns
* **Economic analysis**: Levelized costs, capacity factors, system efficiency
* **Environmental impact**: Total emissions and carbon costs