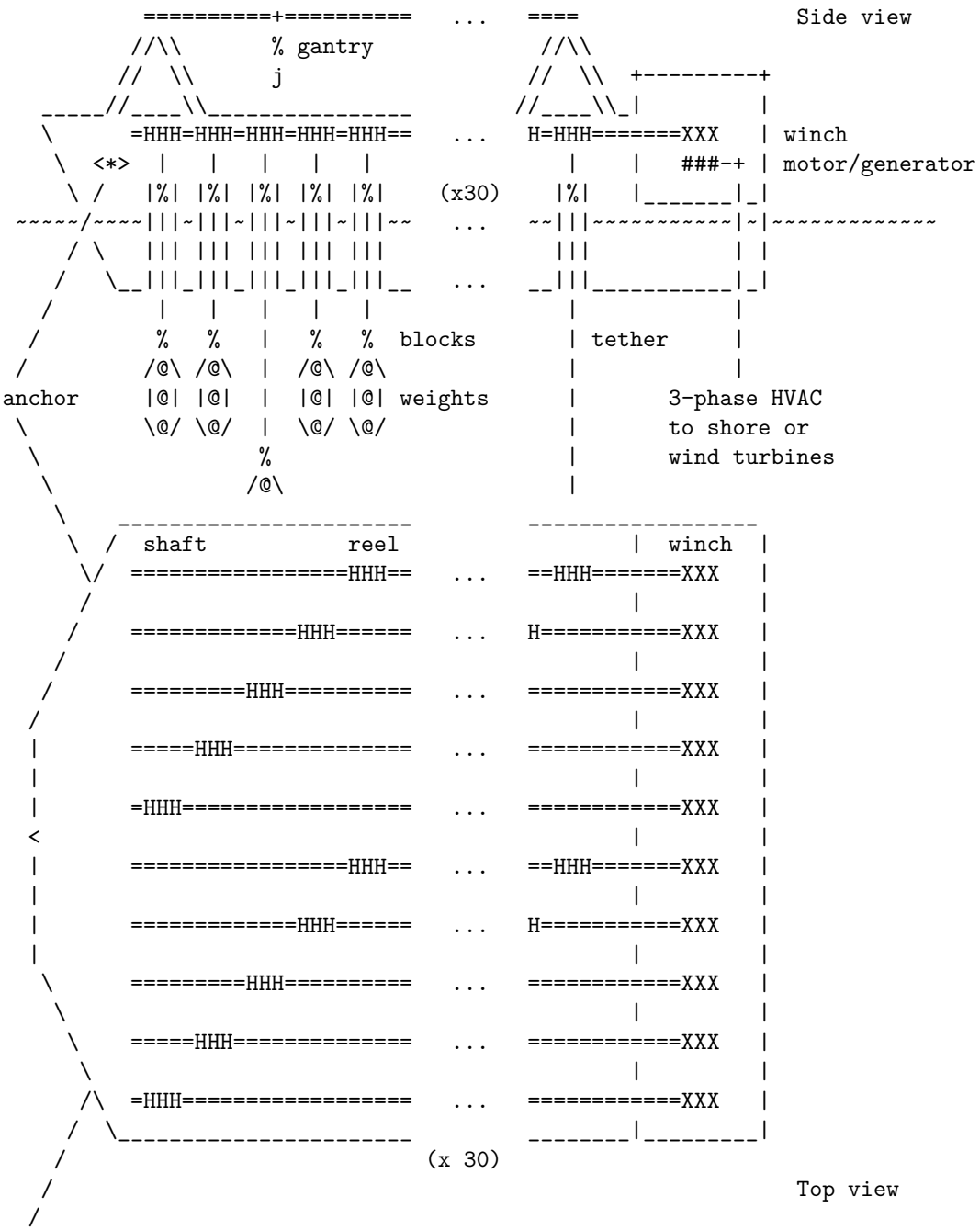
Manifesto: Deep-ocean Energy Storage

Scrap supertanker or container vessel, less engine, 300,000 tons net displacement:



Legend:

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~~~ : Water line
### : 10x 10MW motor/generators, protected from weather
XXX : 10x < 200t crane winches
=== : 10x parallel shafts running length of vessel
HHH : 300x tether reels, 30 on each shaft, coupled with clutch/brakes
 |  : 300x tethers to hanging weights
||| : 300x "moon pools" from ship bottom to above water line
|@| : 300x 1000-ton weights, peridotite riprap in cargo nets
 %  : 300x block/tackles
 j  : Gantry crane for construction and maintenance
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Principle of operation: Weights suspended high above the sea floor store potential energy E = mgh, extracted by unreeling to drive a generator, recharged by hoisting them back up, with round-trip efficiency over 80%, instantly dispatchable.

Design goals

1. Few expensive parts (motor/generators, winches, vessel) are amortized across abundant stored energy. Per-unit parts, such as reels, clutches, tethers and weights, are relatively cheap and simple.
2. Energy-storage media is easy to add incrementally, providing service immediately from a partially-constructed system, similar to solar and wind installations.
3. Conversion efficiency is high both in and out.
4. Power in and out is continuously and instantaneously variable to adapt to changing grid conditions and stabilize grid.
5. Multiple, independent subsystems contain effect of equipment failures, eliminate most causes of whole-system downtime.
6. Mature, off-the-shelf tech keeps costs down and reliability up.
7. All electrical equipment is under cover, out of weather.
8. Operational expense is near-zero, normally all remote.

Details:

1. Each tether reel `HHH` winds one tether loaded to 100 tons.
2. Tethers run straight down through a *moon pool*, a vertical tunnel from ship hull bottom to above the water line, below each reel. A 10x pulley block is supported in each tunnel, above the water line.
3. Reels couple to their drive shaft `===` via a clutch/brake. This is the only mechanical part besides the drive train. Failure of a clutch affects only the

one reel, or at worst the shaft it is on.

4. Each shaft is directly coupled to a winch `XXX` and its motor/generator `###`. Shaft is bolted in sections for easy service, supported along its length between reels on roller bearings.
5. Each winch only ever lowers or hoists one or two weights at any time, the rest decoupled via their clutches, so may be rated to only 200 tons, for easy sourcing.
6. Per reel, gravitational potential energy per meter is E/h = mg, 1000 tons x ~10 m/s^2 = ~10 MJ/m. Assuming 2000m working depth, each weight stores 10MJ/m x 2000m = 20 GJ = ~5 MWh.
7. Operating a reel at full speed, 10 MW moves one weight up or down at 1 m/s. Operating all ten motor/generators at once, system handles 100 MW total power, in or out. Turbulent friction is negligible.
8. All 300 reels together thus store 1.5 GWh, or 15 hours at full wattage.
9. Weights are cargo nets loaded with riprap, lozenge-shaped and wrapped to minimize drag when in motion.
10. Accounting for buoyancy, 1250 tons of peridotite riprap at $5t/m^3$ provides 1000 tons of load on a tether. At 4m diameter, stands 20m tall.
11. A gantry running the full length and breadth of the vessel enables service to all system components *in situ*, and incremental construction. A vessel fitted with only one shaft is already useful.
12. Reels may be constructed concentric with their drive shaft. Clutch and brake may be implemented by clamping adjacent ring flanges extending from the reel, shaft, and bearing.

Bill of Materials

- Scrap supertanker or container vessel, $50M
- Gantry, $10M
- 10x 10MW motor/generators, $100M
- 10x 1000t-rated winches, $5M
- 320x heavy-pipe drive-shaft sections, $10M
- 320x drive-shaft support roller bearings, $10M
- 300x clutch/brakes, $30M
- 300x cable reels, $5M
- 300x moon-pool pipes, $10M
- 300x 20 km 100t-test tethers, $10M
- 300x 10x block+tackle pairs, $1bM
- 30000x cargo nets, $10M
- 300,000t peridotite riprap, $5M
- 1 HVAC cable to shore or wind farm, $10M

Estimated total cost, < $300M per 1.5GWh storage, < $20/kWh.

Notes

1. Vessels may be racked side-by-side for greater storage capacity and stability.
2. Racked vessels may host on-board wind turbines.
3. Racked vessels may be ranged to provide protected, calm water between, for e.g. floating solar farms or aquaculture.