BattMarines

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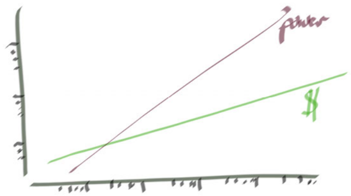
Introduction

- For many decades electric energy was provided by conventional power plants

- Can‘t we learn from existing technology for storage applications?

Introduction

- Features of typical conventional power plants
  - “Machine” is expensive while fuel or working media is cheap
    → Increase size of machine saves cost
    “Big is beautiful”
  - But need for energy distribution through grid



- Features of electrical energy storage devices (batteries)
  - “Storage media” is mayor invest
    → Scaling to large dimensions does not result in desired savings
  - Storage at consumer/prosumer site possible

A “naïve” proposal

Apply the traditional “big is beautiful” approach and scale to GWd size.

- Prerequisite:
  - Storage media must be cheap and common
  - Energy density must be reasonable high
  - Scaling to very large dimensions must be feasible

A “naïve” proposal

Storage media:

- Gases: air, steam

- Soil
- Water

- Phase-changing materials
- Chemical/electrochemical reacting media

A “naïve” proposal

Storage media:

- Gases: air, steam
  - Compressed air
  - Liquid air
- Soil
  - Geothermal
- Water
  - Hydropower
  - Hydrothermal power
- Phase-changing materials
  - Salt (solid-liquid), Air/Water (liquid-gas), …
- Chemical/electrochemical reacting media
  - Electric batteries: Lead, lithium, …
  - Power2X: Hydrocarbons, Silanes …

A “naïve” proposal

Current workshop considers Carnot-processes which are also employed in modern thermal power stations

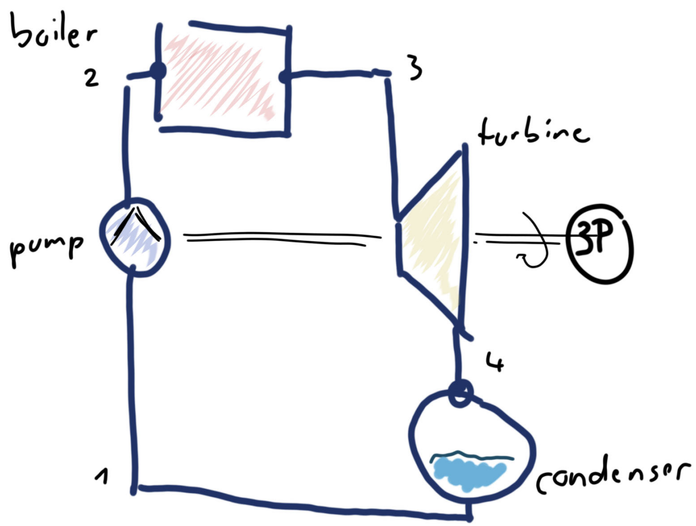
- Lets learn from “state of the art” hydrothermal power plants:
  - Steam turbine power plants are most common technology
  - Carnot efficiency is best at high temperature (ratio)
  - High steam quality yields high power output

  - Optimum size at market is of order 100-1000MW
  - Operation at high pressure (sometimes supercritical pressure)

The proposal

Run “state of the art” steam turbine power plant in batch operation and store the high quality steam in large quantity as a Carnot battery system.

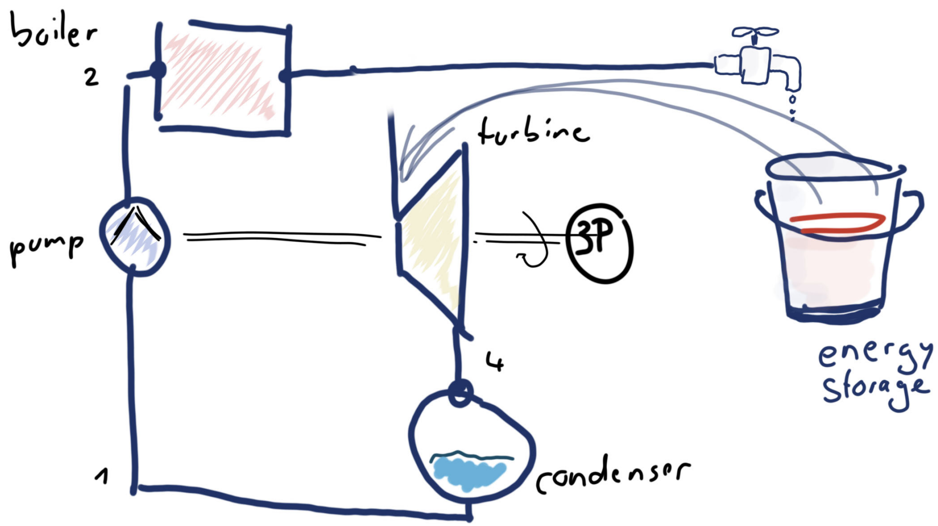
- 1→2 pump to high p
- 2→3 heat to high T
- 3→4 expand in turbine → electric power
- 4→1 heat sink



The proposal

Run “state of the art” steam turbine power plant in batch operation and store the high quality steam in large quantity as a Carnot battery system.

- 1→3 charge
- 3→4→1 discharge



Validate the proposal

Why is this not a common approach?

Estimate some parameters:

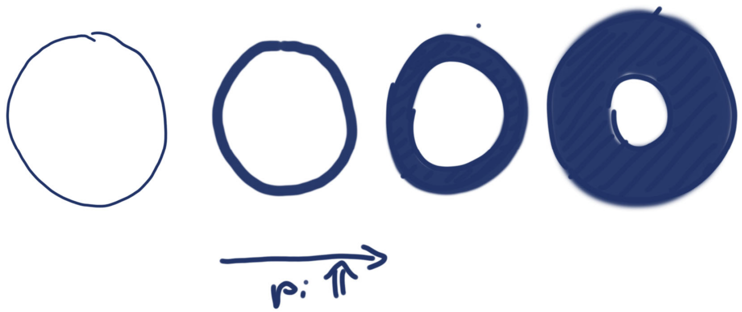
- Steam at T>500°C and p>100bar (better T>550-700°C and p>250bar)
- Minimum operation time must exceed several hours so that a huge high pressure-high temperature vessel is needed.
- Heat losses will be large and may corrupt desired efficiency.

Are similar vessels available?

Validate the proposal

Unfortunately, in common applications hot water is stored at low or ambient pressure.

- Wall thickness (cost) of pressure vessels rapidly grows when increasing overpressure



Validate the proposal

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Seek special applications that can enclose large quantity of hot steam and high pressure

- No special solutions can be identified that have desired scale and parameters
- Nuclear power containment has appropriate scale and can withstand several bar of overpressure.
- Geothermal aquifers at large depth may contain water at the desired parameters. However, direct storing of hot water/steam in aquifers brings steam in contact with soil, so that it is contaminated with soluble compounds.

- Modified proposal uses large scale vessel at large depth as a barrier between the ambient environment ruling out contamination of “stored” steam.

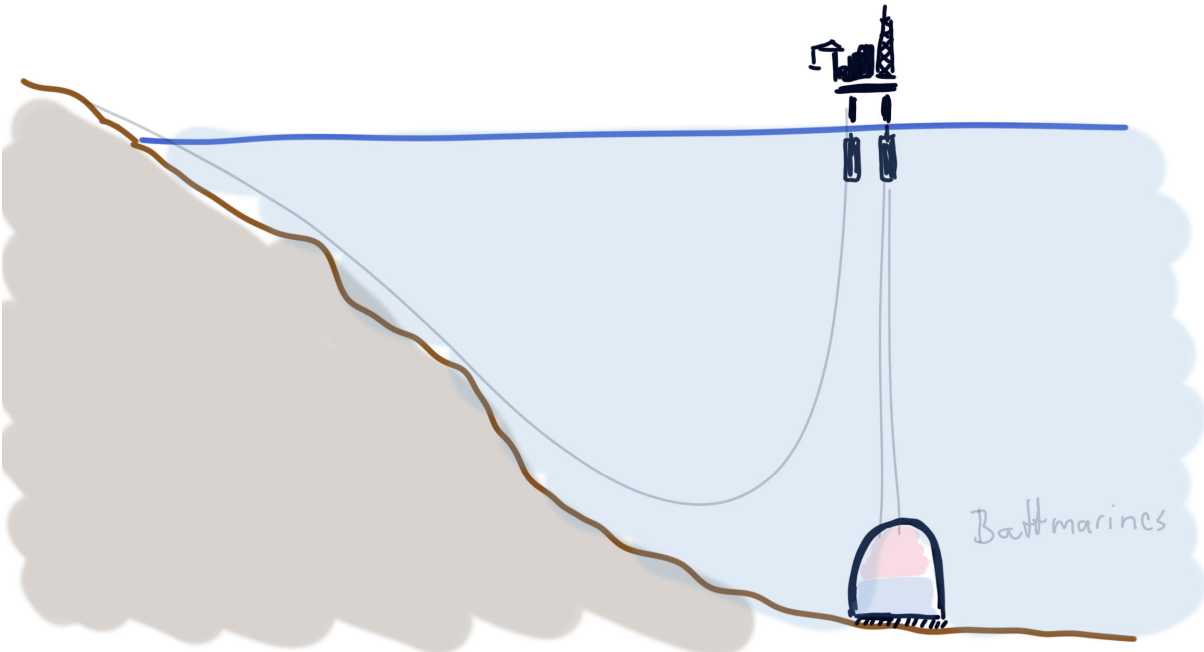
Final proposal: BattMarines

Submerge a vessel of dimensions similar to nuclear containment deep into the sea to store large quantity of high quality steam for periods beyond 20 days.
Connected to common steam turbine power plant components.

- “Thin shell” vessel will reduce the cost of the vessel
- Common components reduce the cost of the attached power plant

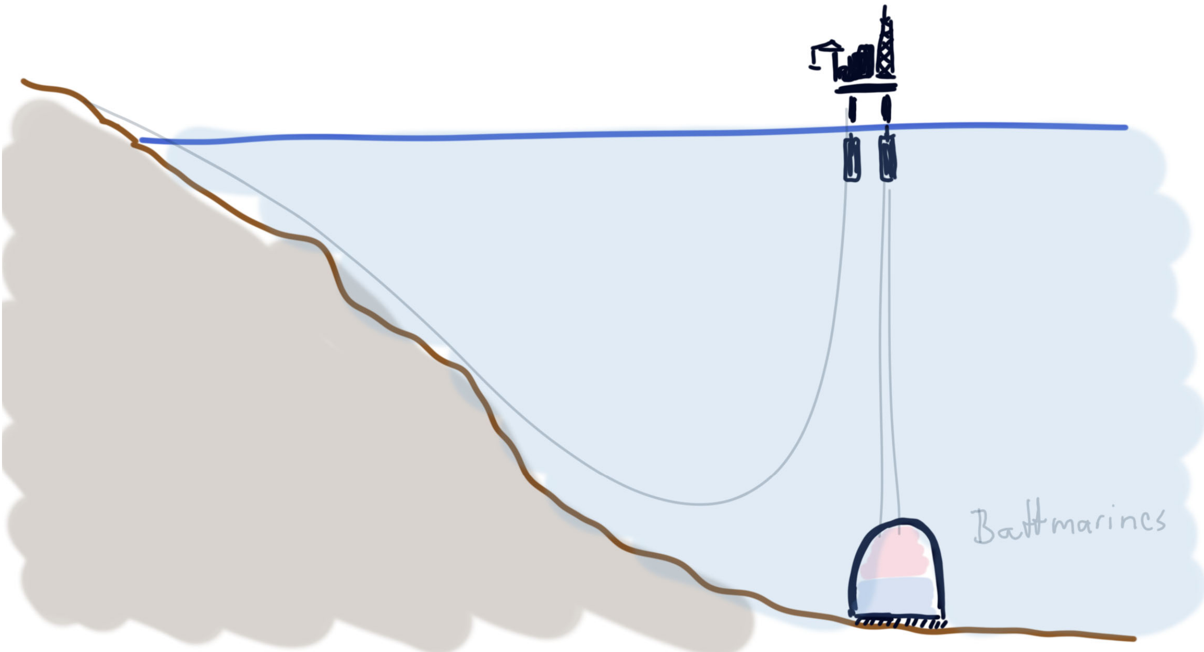
- However, there may be simple pitfalls that become showstoppers.

Final proposal: BattMarines



Final proposal: BattMarines

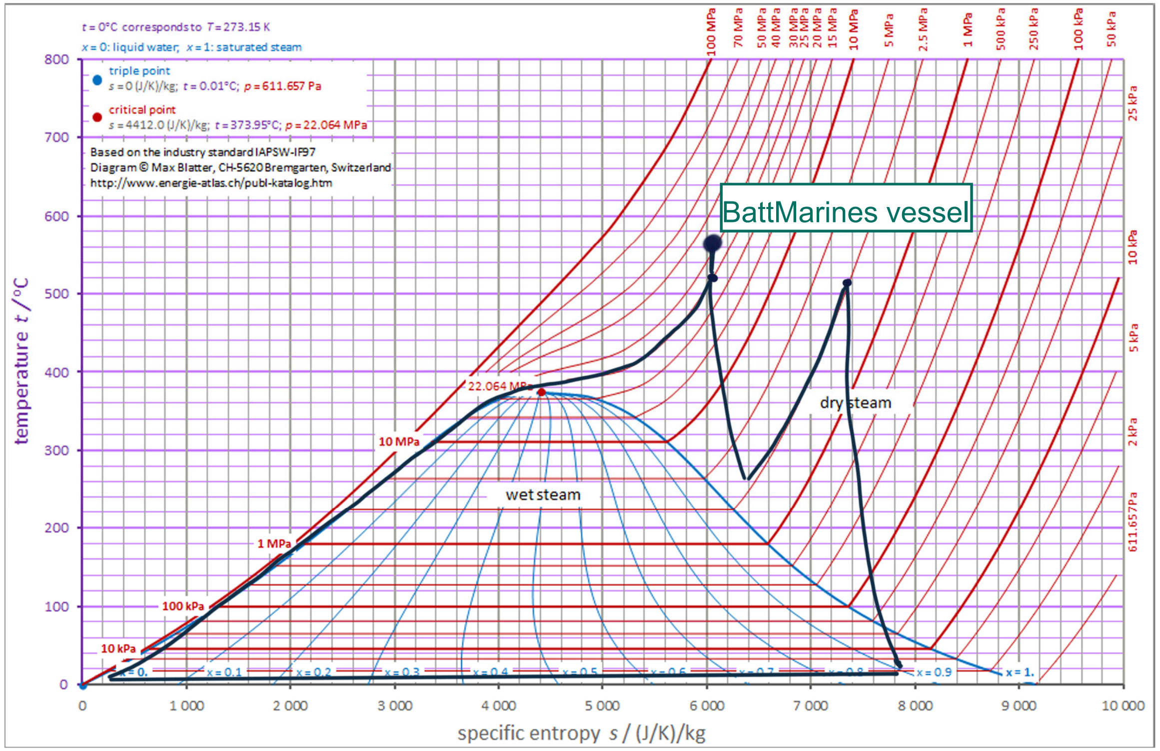
- For desired pressure needs depth of >2000m



Final proposal: BattMarines

Rankine Cycle
with turbine extractions
for reheating.

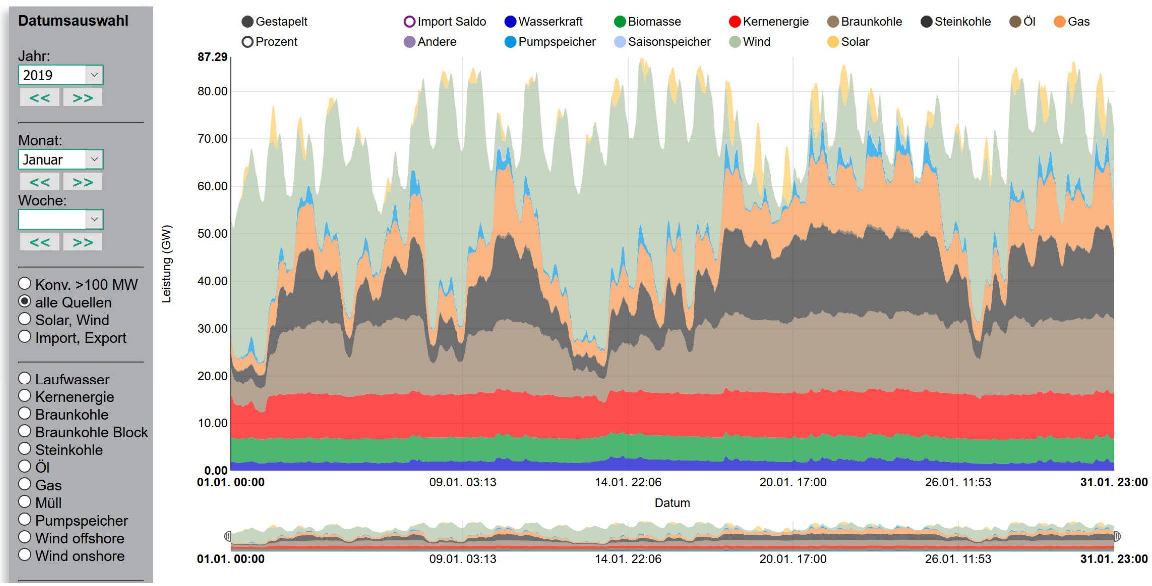
Note: near-isentropic
compression/expansion
in vertical steam line



BattMarines - pitfalls we looked at

No need for storage capacity that large?

- Data shows periods of multiple days where tenth of GW are needed
- Market for many BattMarines (provided prize is ok)



https://www.energy-charts.de/power_de.htm

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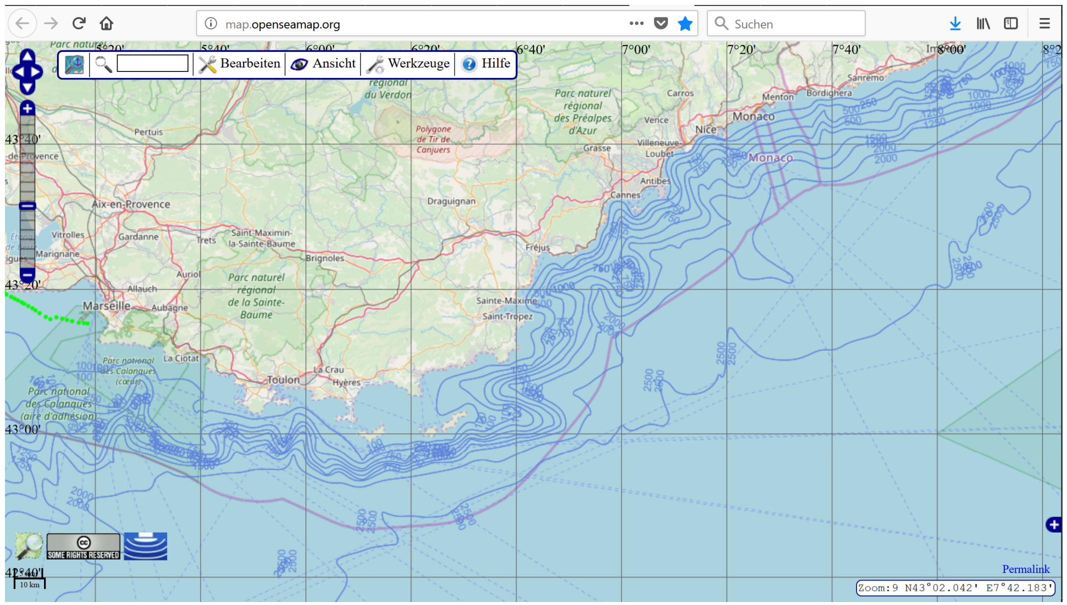
BattMarines - pitfalls we looked at

No suitable locations?

- Depth of >2000m close to coast line
- Good grid connection

- France: Marseille/Bordeaux
- Spain: Baleares
- North African coast
- Portugal: Lisbon
- …



www.openseamap.com

BattMarines - pitfalls we looked at

Dimensions of BattMarines larger than humans can handle?

- $\Delta h \sim 700 kJ/kg$
- $v \sim 0.01 m^3/kg$
- $1GWd \sim 10^{14} J$

- Need for ~ 10^8kg or ~10^6m³ of steam

- BattMarines needs a vessel with inner dimension of order of 100m

- This is dimension of nuclear containment, ships, and other human constructions

BattMarines - pitfalls we looked at

Common insulation materials cannot be used at 250 bars?

- In marine buildings concrete is commonly used material.
- Using “conservative” thick wall of concrete (~4m) to insulate BattMarines vessel results in heat losses of < 1% per day
- Cost of concrete would be < 100M€ (rough estimate)

  = smaller/similar cost compared to steam turbine power plant on platform

BattMarines - pitfalls we looked at

Due to buoyancy BattMarines will float and cannot be fixed by cables to the sea bed (argument of civil engineers working in nuclear containment design)

- Overcompensate buoyancy with ballast sand
- Active buoyancy control as in submarines including trimming tanks.
- Docking station built at seabed

BattMarines - pitfalls we looked at

Concrete cannot be cast at large depth

- BattMarines is built while floating at surface and then flooded like a submarine to sink
- Neutral buoyancy must be actively controlled since equilibrium is unstable
- Stabilization with cables connected to swimming platform
- Maintenance by surfacing of BattMarines

BattMarines - pitfalls we looked at

BattMarines needs material similar to superheaters in boilers which "cost a fortune"

- Learn from other high temperature industries (ironworks, etc.…)
- Separation of functions:
  - pressure hull from high-alloy steel
  - Insulation: "brickwork" lining
  - Water and temperature resistant ceramic tile plating
  - May use steam generator similar to boiling water steam generator with expensive alloy, while all other components can be built from lower cost alloys

BattMarines - pitfalls we looked at

2500 m long steam line

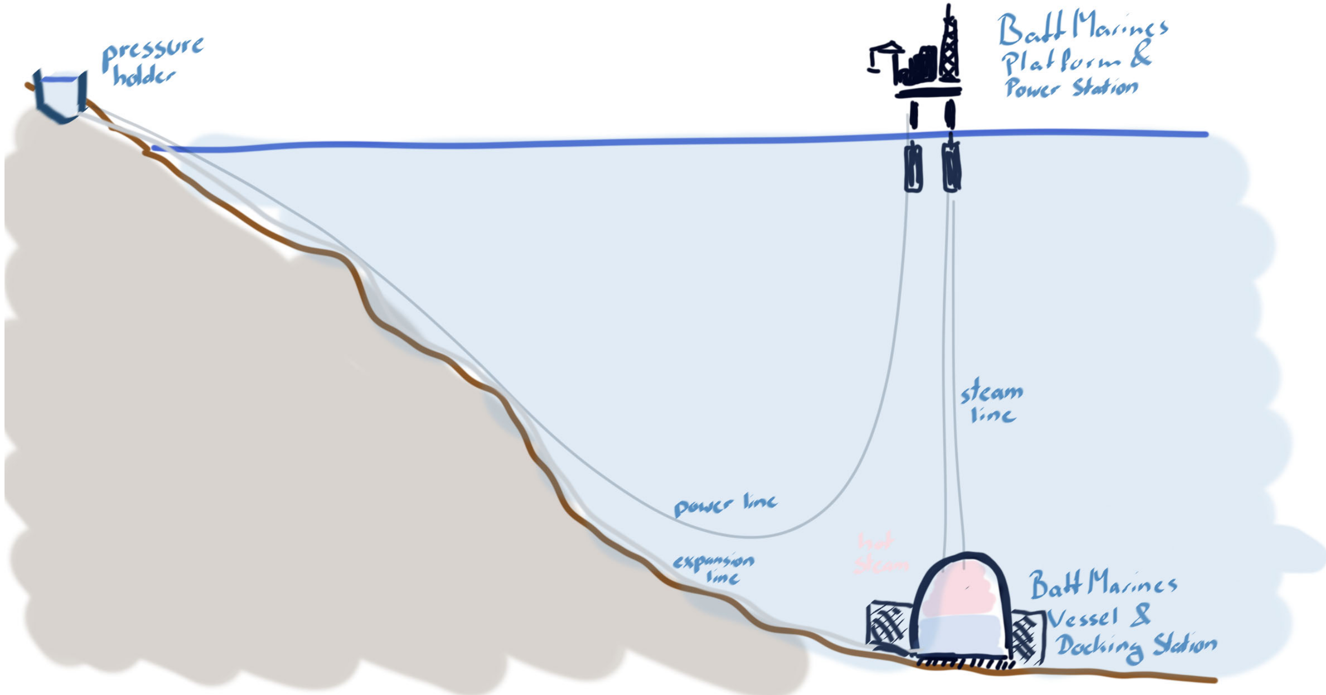
- Steam partially depressurizes in steam line. Reduction of efficiency of Carnot cycle. “Light” steam limits pressure change to ~20 bars
- Crosssections of steam and fresh water lines as in conventional steam turbine power plants.
- Challenge to dimension these lines properly and to account for expansion compensation and maximum stress control.

BattMarines – pitfalls we looked at

Other aspects we have looked at:

- Mixing of water coolant with seawater = need for expansion volume
- Intermediate coolant loops with heat exchanger within BattMarines and other media in intermediate loop (sodium, oil…)
- Building location far from sea in salt domes or granite
- Potential insulation materials
- …

BattMarines



Conclusions

We tried to identify showstopper

- Each time we presented BattMarines new potential show stoppers arose.
- We are no experts in many relevant topics but yet we found approaches to tackle critical aspects.
- Please help us finding critical aspects.

Outlook

If you like the BattMarines proposal and its numerous challenges, we would be happy to initiate a joint team of experts in the fields:

- energy engineering
- thermohydraulics, system-code modelling
- civil/structural engineering
- marine/naval engineering
- geology
- mining/drilling engineering
- material science, corrosion engineering
- ….