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ULSTEIN THOR & ULSTEN SIF – Short description

ULSTEIN THOR is a 149m 3R (Replenishment, Research and Rescue) vessel design launched by Ulstein as a mobile power/charging station for a new breed of full electric vessel operations. The vessel features a Thorium Molten Salt Reactor (MSR) that generates 20 MWe of clean, safe electricity to be supplied to other ships.

A replenishment vessel like ULSTEIN THOR will be able to generate clean energy that will be transferred to several vessels and be a game changer within the decarbonization of shipping operations. Challenges like availability of alternative fuels, their high costs and large storage volume requirements are overcome by installing a molten salt reactor into a replenishment vessel. This replenishment vessel (ULSTEIN THOR) will charge other vessels with clean energy. Thus, reducing the need for specialized personnel, reducing the number of vessels carrying nuclear fuel and gaining more competitive energy prices by economies of scale.

Three of the main challenges for the implementation of nuclear power in the form of molten salt reactors in ships are the size of the reactors – in most cases too big for the energy demand of a single vessel, the limited availability of expertise to operate and maintain the reactors, and the regulatory limitations imposed by the different flag states and accessibility to ports.

Figure 1. ULSTEIN THOR (blue) and the full-electric cruise vessel ULSTEIN SIF (green). Source: Ulstein Group.

The fluctuation in power demand on vessels will also challenge the commercial viability of MSR on ships, primarily for the vessel types operating mostly at low loads . These challenges

can be solved by placing the reactor on a single replenishment vessel that can produce energy and replenish several other vessels.

ULSTEIN THOR's original design scenario was as a replenishment vessel for expedition cruise vessels operating in Antarctic waters (See Figure 1). From October to March, more than 50 cruise vessels perform expedition tours in the Antarctic peninsula.

A reference number for the energy consumption of a vessel crossing the Drake Passage between Antarctica and Ushuaia is about 130 MWh. This operation takes about 2 days. While in Antarctica, the energy consumption is lower, and a reference is about 100 MWh for a five-day trip.

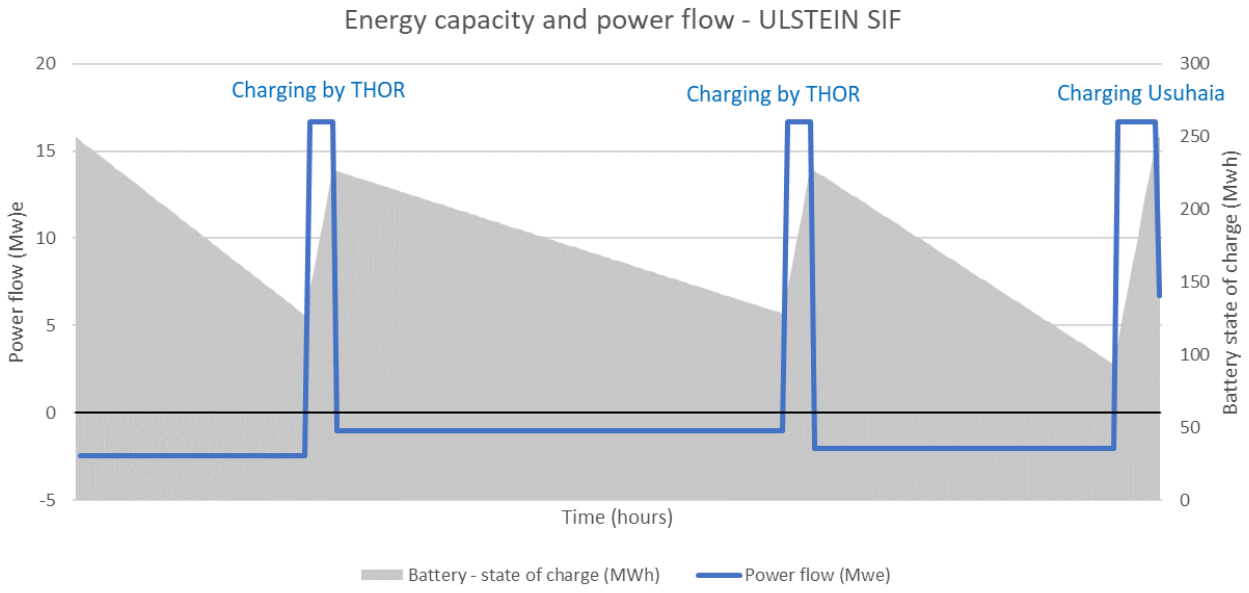

Figure 2. Example of charging schedule for ULSTEIN SIF. Source: Ulstein Group.

Based on these numbers, we can develop a charging schedule for one vessel considering two offshore recharges per round trip – one when arriving at Antarctica and one before starting the return trip through the Drake Passage, and finally one recharge at port in Usuhaia. Figure 2 represents an example of the energy balance and charging schedule for a full electric cruise operating on this route. In each of the two recharges ULSTEIN SIF's battery will be loaded with 100 kWh at a rate of 16,7 MW per hour.

Each cruise vessel will spend 6 hours charging from ULSTEIN THOR. The capacity of THOR is designed so it can charge one cruise vessel at a time, and a total of four vessels per day (4 x 6 hours charge).

Given the dimensioning criteria for THOR and the typical schedule of cruise vessels operating in Antarctica, THOR would be able to provide energy for a maximum of 15 small cruise expedition vessels per season. If we extrapolate this schedule to a 150-day operation (typical

annual campaign), we identify that the daily energy replenishment demand for the vessel ranges between 200 and 300 MWh.

Considering this scenario, ULSTEIN THOR would generate over 50 GWe of energy in a single cruise campaign of 150 days. Consequently, making an impact on the environment in Antarctica in the magnitude of over 32,000 tonnes of CO2 not emitted to the environment.

The power demand of ULSTEIN THOR will be driven by the capacity to recharge the cruise vessels it replenishes. The power demand for THOR will vary substantially during the day and over its operation. Power demand will be at its peak when THOR is recharging cruise vessels and will drop when no vessels are connected to it. Thus, THOR's power plan needs to be flexible. A realistic dimensioning for the reactor is 20 MWe at peak capacity, enabling the supply of peak capacity, own consumption and a marginal excess for potential additional needs. With a 20MWe reactor, the power plant could be complemented by four 5MWe close-cycle steam turbines. Hence, the power output of the reactor can be easily adapted to different levels of operation. A simple single-line diagram of the power plant is presented in Figure 3.

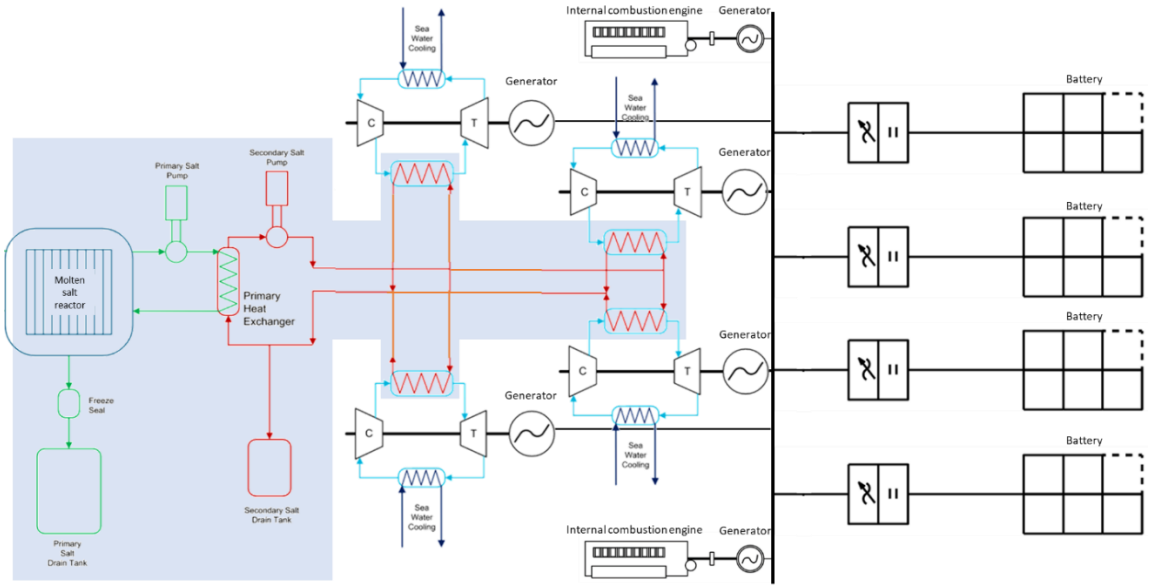

Figure 3. Simplified single-line diagram. Source: Ulstein Group.

The diagram in Figure 3 reflects a thorium power plant for a ship with one reactor and four close-cycle steam turbine generators for electrical power production. The system consists of three salt circuits. The primary (green) and secondary (red) salt circuits and the fuel drain tanks are housed within a flexibly mounted fully enclosed rafted structure. The tertiary salt circuit (blue) is considered outside the radioactive zone. The salt drain tanks are situated vertically below the reactor vessel and secondary salt circuits, within the bottom cell of the reactor raft, and being actively heated requires both radiological and thermal protection.

The main elements of the power plant and propulsion system of the vessels are represented in Figure 4.

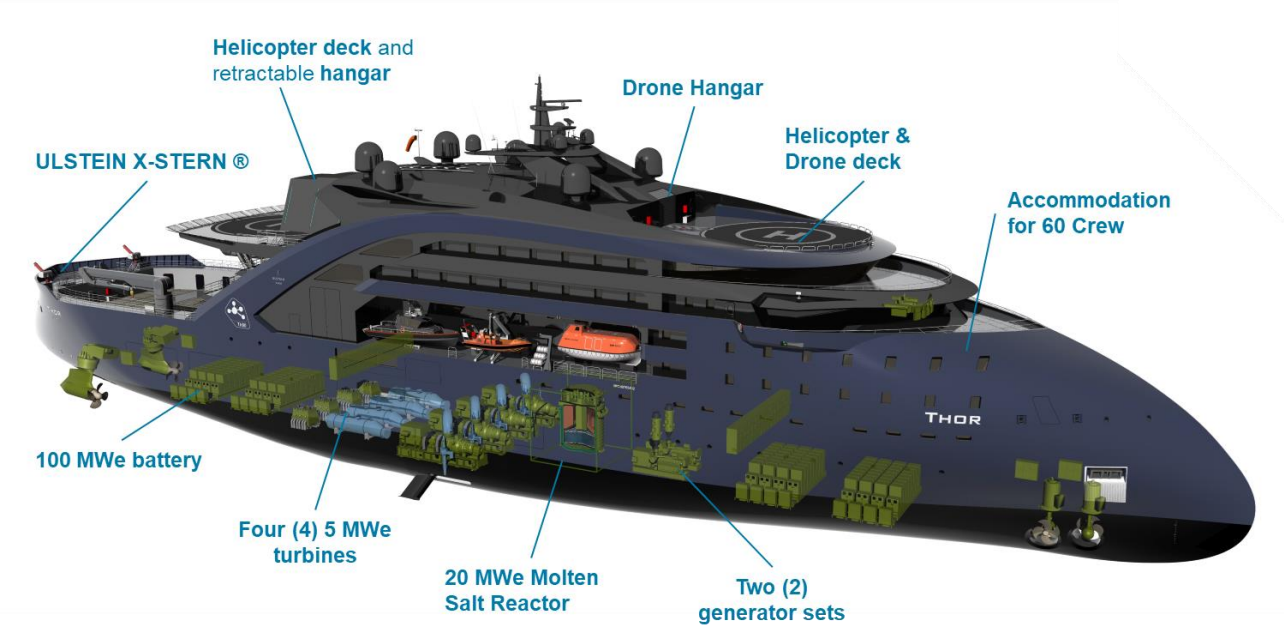

Figure 4. ULSTEIN THOR – highlight of main components of power and propulsion systems. Source: Ulstein Group.

Early discussions with classification societies have made it clear that a redundant energy source will be mandatory. Thus, two sets of marine generator sets are also included in the power plant. This complementary power plant does not need to cater to the full power capacity of the vessel but rather supplies power to critical and essential systems only.

ULSTEIN THOR in numbers
149 m LOA x 25 m Beam
20 MWe molten salt reactor
Four 5 MWe turbines
100 MWh battery
Energy replenishment for up to four cruise vessels per day

ULSTEIN SIF in numbers
100 m LOA x 16,5 m Beam
60 to 80 passengers
60 to 80 crew
300 MWh battery
6 hours charging @ 16,7 MWe
Full electric operations

ULSTEIN THOR in numbers
100 MWe of green electricity per replenishment operation
Up to **four recharge** operations per day
Up to **15 vessels** being replenished by one ULSTEIN THOR
50GWe of green electricity replenished per **cruise season**
32,000 tonnes of CO2 saved per season