Brief Description of the Muuga Seawater-Pumped Hydro Accumulation Power Plant

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**Contents**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFACE</td>
<td>3</td>
</tr>
<tr>
<td>1. GENERAL DESCRIPTION OF THE SEAWATER-PUMPED MUUGA HYDRO</td>
<td>4</td>
</tr>
<tr>
<td>ACCUMULATION POWER PLANT</td>
<td></td>
</tr>
<tr>
<td>2. WATER INTAKE</td>
<td>7</td>
</tr>
<tr>
<td>3. HEADRACE CHANNEL</td>
<td>7</td>
</tr>
<tr>
<td>4. TURBINE HALL</td>
<td>8</td>
</tr>
<tr>
<td>5. TAILRACE CHANNELS</td>
<td>8</td>
</tr>
<tr>
<td>6. LOWER ELEVATION WATER RESERVOIR</td>
<td>8</td>
</tr>
<tr>
<td>7. ACCESS SHAFTS AND TUNNELS</td>
<td>9</td>
</tr>
<tr>
<td>8. CABLE SHAFT</td>
<td>9</td>
</tr>
<tr>
<td>9. SUBSTATION</td>
<td>9</td>
</tr>
</tbody>
</table>
PREFACE

This work is based on the preliminary research on Maardu hydro accumulation power station, carried out by ÅF-Estivo, which is focused on the construction of the hydro accumulation power plant to be built by OÜ Energiasalv.

In addition to the alternatives looking into different prospective locations and capacities of the hydro accumulation power plant discussed in the afore-mentioned preliminary research, the developer wishes to have an insight into the new location/capacity alternative.

The new alternative involves a seawater-pumped hydro accumulation power plant with the capacity of 500 MW. The on-the-ground complex shall be located in the territory of Muuga Harbour Industrial Park. Water intake shall be located on the northern slope of the Muuga Harbour eastern breakwater.

According to the Contracting Entity’s wish, this report provides a brief overview of the main components that the new alternative of the hydro accumulation power plant incorporates, and their possible arrangement. The Report does not look into the equipment and technologies used for building underground structures. Neither does it examine the components of the on-the-ground complex (the granite excavating and hoisting equipment, a crushing plant, a storage for processed materials and the facility for loading materials into trains and trucks). The scope of works does not include estimations of the volumes and investments of excavation and support-setting works that the hydro accumulation power plant development involves. The projection of economic activities is not included in the scope of works either.

This Report is on 10 pages and includes 4 figures.
1. GENERAL DESCRIPTION OF THE SEAWATER-PUMPED MUUGA HYDRO ACCUMULATION POWER PLANT

The use of seawater in hydro accumulation power plants is an idea proposed long ago, but according to the information known, only one such type of hydro accumulation power plant is in operation in the whole world at present. It was built in Okinawa Prefecture, Japan, in 1999 (Figure 1.1).

![Figure 1.1. The only seawater-pumped hydro accumulation power plant in the world (Okinawa Prefecture, Japan).](image)

While planning and designing the Okinawa power plant, a lot of attention was paid to the selection of construction materials in order to prevent corrosion.

Some details usually made of carbon steel were replaced by the stainless steel ones during the turbine modelling and designing process. Besides, the structure of turbine was modified in order to facilitate future repairs. Cathode rusting protection was used to prevent corrosion.

While planning the Okinawa hydro accumulation power plant, analysis was also made on the sticking of small marine organisms to turbines, pipelines, control gates and auxiliary equipment – a process which affects the turbine efficiency and increases a need for maintenance works. The problem was solved by optimising water flow rates in different sections of water channels and by applying water-resistant non-stick paint.

Taking into account the experience of Okinawa hydro accumulation power plant in planning this power plant, it is important to bear in mind that here we have to do with a non-standard solution, which requires a thorough research into the pollution and corrosion conditions of the turbine and other water contacting steel structures and, thus the best solution for preventing...
any possible problems must be found. It is unlikely that the standard type pump-and-turbine assemblies provided by manufacturers can be used at Muuga hydro accumulation power plant.

The uniqueness of the observed alternative lies in the fact that, contrary to the Okinawa power plant, the sea forms the upper reservoir by us.

The designed location of the on-the-ground hydro accumulation power plant and granite handling complex shall be in the region of Muuga Harbour Industrial Park, which covers the area of 56,220m$^2$. Water intake will be located on the northern slope of the Muuga Harbour eastern breakwater, not far from the coal terminal (Figure 1.2).

![Figure 1.2. Location planned for the on-the-ground hydro accumulation power plant and granite handling complex.](image)

The on-the-ground complex shall incorporate the hydro accumulation power plant control centre, substation, main elevation tower, auxiliary elevation tower, crushing house, a storage for processed materials, facility for loading materials into trains and trucks and other structures/equipment if needed.

The designed nominal power of the seawater-pumped Muuga hydro accumulation power plant is 500 MW. The hydro accumulation power plant shall have three reversible vertical-shaft Francis-type pump-turbine assemblies (1x100 MW, 2x175 MW) and one 50 MW vertical-shaft Francis-type turbine (the number and nominal capacities of turbines may be modified during the preparation of final design).
The illustrative schematic diagrams of the observed alternative, including the primary technical indicators, have been set out in Figure 1.3. The diagrams in the referred Figure indicate the possible arrangement and position of the hydro accumulation power plant-related engineering structures and equipment at the planned site.

The turbine hall shall be located close to the main shaft intended for hoisting the excavated granite onto the ground and for the air outlet, and near the ventilation shaft intended for the entrance of people and equipment and for the air inlet.

Figure 1.3. Schematic diagram of Muuga hydro accumulation power plant.
The following chapters will focus on the main engineering structures and components of the Muuga hydro accumulation power plant alternative (Figure 1.4):

- Water intake;
- Turbine hall;
- Tailrace channels;
- Underground water reservoir;
- Cable shaft;
- Entrance and ventilation shafts.

### 2. WATER INTAKE

Water intake is located on the northern slope of the Muuga Harbour eastern breakwater, from where the seawater is controlled to flow to the headrace channel leading to the turbine. Trashrack and sluice gate shall be installed in the water intake.

The flow rate in the racks of water intake must meet the environmental requirements. The structure of water intake and the equipment installed therein must prevent ice and slime from drifting into the water intake and from leaching onto the sea floor at the water discharge, and avoid storm water and refuge originating from the coast from being carried into the water intake.

### 3. HEADRACE CHANNEL

Headrace channel is intended to carry water from the upper reservoir (sea) up to the turbines (electricity generation mode) and from the turbines up to the upper reservoir (pumping mode).
From the technical-economic perspective, it is rational to construct the headrace channel section, which permeates low-density rocks, as a vertical shaft.

The headrace channel slanting tunnel dredged in the granite connects the vertical section of the headrace channel with the horizontal pressure shaft (penstock) which branches off before turbines. Through the branching-off pressure shaft, which is usually a steel pipe, water is carried to the turbines.

The minimal inner diameter of headrace channel is ~7 meters, by which the water flow rate does not exceed 3.1 m/s when the hydro accumulation power plant is operated at full capacity. The water flow rate 3.1 m/s was used in designing similar plants in Sweden and regarded as an optimal compromise between losses occurring in the channel and the investments depending on the diameter of the channel to be built.

4. TURBINE HALL

The turbine hall, situated below the lower reservoir, ensures the pump-and-turbine operation in the pumping mode.

The estimated position of the turbine hall is between the water surface absolute elevations -565 m and -530 m.

The main equipment to be installed in the turbine hall incorporates three reversible vertical-shaft Francis-type pump-and-turbine assemblies (1x100 MW, 2x175 MW) and one 50 MW vertical-shaft Francis-type turbine, including generators, auxiliary equipment and the overhead crane.

The turbine hall must have an access to the sluices of tailrace channels.

5. TAILRACE CHANNELS

Tailrace channels are intended for carrying water from the lower reservoir to the turbines (pumping mode) and from the pumps to the lower reservoir (electricity generation mode).

The tailrace channel consists of a horizontal widening channel going out of the turbines (horizontal section) and a vertical downstream channel connected to the lower reservoir (vertical section).

Tailrace channels shall be supplied with sluices and, if needed, with refuge collection equipment.

6. LOWER ELEVATION WATER RESERVOIR

Chambers in the granite layer formed as a result of granite excavation shall be flooded and used as the lower reservoir. For that purpose, the granite excavation works technology shall be applied.
The total volume of lower reservoir must ensure 12-hour operation of the hydro accumulation power plant at the nominal capacity (water consumption 4.75 million m$^3$). A necessary number of chambers shall be dug for that respect. The required dimensions and number of chambers shall be calculated on the basis of strength measures and economic indicators.

In designing the hydro accumulation power plant, it is desirable that the difference in the operational heights of the turbine should not exceed 15% of the nominal height. A bigger difference in heights might remarkably reduce the pumping and electricity generation efficiencies and thus reduce the overall efficiency of the plant. If the sea is used as the upper elevation reservoir, then the water level is constant and the desirable difference in the water level of the reservoir must be less than 75 m.

In case the difference in the operational heights of turbines which was selected when designing the hydro accumulation power plant remains less than the designed height of chambers, the total volume of chambers (more than 4.75 million m$^3$) should respectively be increased.

A need for setting supports to chambers depends on the density of granite. In case of high-quality granite, the use of anchor bolts for supporting unstable rocks or some layers could be sufficient. As the operation of plant involves a flow of large quantities of water, it is advisable to support the crumbled and fractured zones in the mine by coating them with sprayed concrete in order to prevent erosion.

7. ACCESS SHAFTS AND TUNNELS

The main and ventilation shafts in the granite mine, excavated for the formation of lower reservoir, which are connected with the turbine hall by a tunnel dug through granite (width ~6.5 m and cross-section 30 m$^2$), ensure access to the turbine hall and are also meant for the transportation of equipment and structures during the construction works and future services and repairs.

The actually required dimensions, lengths, positions and connection points of access tunnels and shafts shall be specified while technical solutions for the erection of engineering structures of the hydro accumulation power plant are being prepared.

8. CABLE SHAFT

All cables necessary for providing power supply to the equipment located in the turbine hall and for connecting the turbine generators to the substation, as well as the automation and control cables shall be assembled into the cable shaft.

9. SUBSTATION

Main transformers constitute the main equipment of the substation. The indicators and position optimal from the technical-economic perspective shall be selected during the
designing of main transformers. The substation shall also incorporate the 330 kV distribution equipment, high-voltage lines, control systems, overvoltage protection equipment, earthing conductors and foundations for equipment, etc. The 330 kV substation must be designed in compliance with the technical requirements laid down by Elering, and in accordance with the Electricity Market Act.