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Short Communication **Open Access**

Design and dimensioning of pressure vessel for a marine substation

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A concept for generation of electricity from ocean waves is being developed at the division of electricity at Uppsala University. The concept is based on linear generators being driven by floating buoys that acts as point absorbers. A linear generator consists of a translator mounted with permanent magnets that moves vertically inside a stator. The stator contains a three-phase coil winding and is placed in a water-tight housing, standing on the seabed. A point absorber is a buoy of small size compared to the average wave-length. The buoy is connected to the translator of the linear generator with a line. The waves set the buoy and translator in motion and voltage is induced in the stator winding. A point absorber connected to a linear generator is called a Wave Energy Converter. The electricity generated from a WEC will have a varying frequency, amplitude and phase order, dependent on the ocean waves. This means that the electricity must be converted with power electronics before it can be used in the grid. Transmitting the electricity from each WEC directly to shore in individual cables would lead to large losses because of the relatively high current and low voltage output from the linear generators. By transforming the electricity to higher voltage near the WECs, losses can be reduced. Conversion of the generated electricity to constant frequency AC and subsequent transformation to higher voltage, can take place in a Low Voltage Marine Substation, LVMS, placed on the seabed in the close vicinity of the WECs. Several WECs can be connected to one LVMS where the generated electricity from each linear generator is rectified. The combined DC is then inverted to 50 Hz AC before transformation to higher voltage. The output from the LVMS will be through a single three-phase AC cable.

The aim of this thesis is to design the pressure vessel for the second low voltage marine substation in the Lysekil project. It will be placed on a depth of 25 m and have an internal pressure of 3 bar. If the vessel is to be pressurized before submersion, the regulations for pressure vessels must be followed when designing the housing. The marine substation will have electrical inputs from seven wave energy converters. The size must be large enough to contain transformers and power electronics for processing the electricity from the connected wave energy converters. It will also have an AC input from the first LVMS, an AC output and a number of sensor equipment outputs. The connectors must be mounted in a way that is adapted for coupling with remotely operated vehicles. The marine substation should be designed to make the lifting and installation on the seabed as simple as possible.

Openings in shells often require that the area around the opening is reinforced to compensate for the reduction of the pressure bearing section. The reinforcement can consist of a nozzle, a ring in the opening, a plate on the shell or increased thickness of the shell around the opening. One method of reinforcement is to use nozzles. A set-on nozzle is a piece of pipe placed on the hole and welded to one side of the shell. A setin nozzle is placed in a hole and welded to both sides of the shell. The method used in EN 13445-3 is called the pressure-area method. It is based on verifying that the reactive force from the material in the reinforcement is equal or grater than the load from the pressure. The reactive force from the material is the sum of the product of the average membrane stress in each component and its stress loaded cross-sectional area. The load from the pressure is the sum of the product of the pressure and the pressure loaded cross-sectional areas.

The design of the pressure vessel will be based on a pressure tank manufactured by Maschinen und Behälterbau GmbH (MABE) in Germany and retailed by Esska teknik in Sweden. The reason for this is economical; to buy a mass-produced vessel and thenmodify it will be cheaper than to manufacture a single customized vessel.

The standard pressure tanks from MABE are available as both horizontal and vertical models in sizes from 50 to 10000 liters. The tanks have dished end of korbbogen type. The vertical 5000 liter model is available with diameter 1400 and 1600 mm. The need for space in the marine substation has been evaluated and the 5000 liter model with diameter 1600 mm has been selected as the most suitable. All MABE tanks are available as models designed for a maximum pressure of 11 or 16 bar. The less expensive 11 bar model will be used as both will have a wall thickness more than sufficient for the marine substation. The MABE tank has four footings on the bottom end. These could be used to attach the tank to the foundation. Some reinforcement might be needed as the footings are not dimensioned for the drag force they will be subjected to when the substation is lifted. Another alternative is to mount the foundation with longer beams attached to the side of the cylindrical shell. The tank also has lifting eyes but they are dimensioned for lifting only the empty tank and will probably be too weak for lifting the substation with its foundation. The MABE tanks are fitted with connection sockets for use with compressed air and a manhole. These features will not be needed on the marine substation. The bottom dished end will also have to be separated from the rest of the shell. The choice will be to either order a tank without these features or to order a standard tank and then modify the unneeded features while the other necessary modifications are made. The latter alternative will involve some unnecessary work but which alternative is the most inexpensive is not obvious since a specially ordered tank will result in a higher price.