Osmotic Energy

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Summary
The need of new energy sources has led to a number of alternatives. Some better than others. One of those alternatives is energy created by transportation of solutions, osmotic energy or salinity gradient energy. In the osmotic process two solutions with different salt-concentrations are involved (often freshwater and salt-water). A semipermeable membrane, which is an organic filter, separates the solutions. The membrane only lets small molecules like water-molecules pass. The water aspires to decrease the salt-concentration on the side of the membrane that contains most salt. The water therefore streams through the membrane and creates a pressure on the other side. This pressure can be utilised in order to gain energy, for example by using a turbine and a generator.

There are several different types of power plants using osmosis (the osmotic process); both land-based plants and plants anchored to the sea floor. The thing the plants we have studied have in common is that osmosis is not directly used to generate power. What the osmosis does is that it creates a flow through the plant and it is that flow that forces the turbine to rotate.

Energy created by osmosis has very little impact on the environment and that is of course an important fact to consider when it comes to determine whether osmotic energy is something to invest in or not. Another advantage is that osmotic energy is renewable, since the process does not "consume" the salt. (Salt-water evaporation leads to precipitation over land.)

The major fact when it comes to the disadvantages is the high cost. Osmotic-produced power is much more expensive than for example fossil fuels. There are also engineering problems to be overcome. The high cost has made us draw the conclusion that osmotic energy is not something for ABB Alstom Power to invest in, at least not in the nearest future, since no one wants to buy the energy when it is so expensive.

The possibility to use osmotic power from our oceans lies within the technology that needs to be developed. There are many possible ways to exploit energy from salinity gradients. It seems, as osmotic pressure will be crucial with each of the possibilities.

**Introduction**

We can't continue using several of our energy sources we gain energy from today. For example fossil fuels contaminate our environment and we are also running out of them. It is therefore necessary to find other ways of producing energy. This report focuses on one of those alternatives, osmotic energy.

Osmosis means passage of water from a region of high water concentration (often freshwater) through a semipermeable membrane to a region of low water concentration (often NaCl). The membrane only lets water molecules pass. Salt molecules, sand, silt and other contaminants are prevented to do so.

Several physiological processes use this osmotic effect. For instance, our body uses it to bring water back from the kidneys, and plants use osmosis to keep the water pressure inside the plant at a fixed level.

Since scientists have found a way to build semipermeable membranes, we can use the osmotic effect and convert it to mechanical energy. We will give examples of different ways of doing this later on in the report. But first we will explain how osmosis really works.

**The osmotic process**

The main thing with osmotic energy is transportation of solutions (often pure water and salt-water), separated by a special filter, a membrane. In the osmotic process it is not possible to use an ordinary filter. You need a "Semipermeable membrane".

A semipermeable membrane is an organic filter with extremely small holes. The membrane will only allow small molecules, like water molecules, to pass through. The thin layers of material cause this and that is what the osmotic energy process is all about.
The picture here on the right shows a simple test rig for this process. The left side contains pure water. The right side contains a solvent with water and salt (NaCl). The only thing that separates them now is the semipermeable membrane. The process is about to begin.

When the process gets started the pure water on the left side aspires to decrease the salt-concentration on the right side of the membrane. The amount of water on the right side will now increase and create an "Osmotic head pressure". We can use this pressure, for example, to force a water- turbine to rotate.

The amount of freshwater that will pass through the membrane depends on the salt-concentration in the salt-water, before the osmotic process begins. For instance, if the salt-concentration from the beginning is 3,5%, the osmotic pressure will be about 28 bars.

The problem with the test rig is that the salt-concentration in the salt-water will decrease and the process will slow down. The only way to fix this is to continuously, empty and refill both the left and the right side. This must be done very quickly to avoid run-interference.

Another problem is that the membrane can, and will wear out because of all silt and other contamination that will get stuck in the membrane. If we don't consider this fact a membrane's length of use is about 6 months. This sort of process could not only be used for energy purpose. The main use area today is Reverse Osmosis, where you create a pressure larger than the osmotic head pressure and push the salt water through the membrane. From this process you gain fresh water out of salt-water.

Different power plants using osmosis

SHEOPP Converter
The picture below shows a SHEOPP Converter, which is a submarine hydroelectric power plant anchored to the sea floor. Fresh surface water, from a river mouth or an aqueduct, is conveyed through a penstock (standpipe) to a hydraulic turbine. After generating electric power, the fresh water is discharged and depressurised into a submarine tank. Finally the fresh water diffuses out in the sea by osmosis, through a barrier of semipermeable membranes.

For pure fresh water and perfect semipermeable membranes a flushing pump would not be necessary and the electric power produced in the SHEOPP Converter would be maximised. In real situations, however, the fresh water will generally contain non-tolerable amounts of dissolved salts and particles like sand, silt and other contaminants. It may then be necessary to pretreat the fresh water and a flushing pump would be required to prevent accumulation of unwanted solutes and contamination on the fresh water side of the membranes, to keep them in good working condition for as long as possible.

The efficiency for the SHEOPP will reach its maximum at a depth of 110 meters.

Underground PRO plant

If an osmotic flow passes through a semipermeable membrane, which separates the two solutions and forces a turbine to rotate, the process is called pressure-retarded osmosis, PRO. Both these plants described here use PRO, but the plant below is land-based while the SHEOPP Converter is anchored to the sea floor.

Fresh water at sea level flows vertically downward through a penstock. The lower end of the penstock is situated about 90 meters below the sea surface where the pressure is 9 bars. This pressure forces a turbine to rotate and the pressure drops to 0 bar. Seawater is pumped from the surface to a barrier of semipermeable membranes (an osmotic unit). By osmosis the fresh water is driven through the membranes, trying to even out the amount of dissolved salt in the seawater. The flushing solution is pressurised to 9 bars and is pumped up to the surface. The diluted solution returns to the seawater by the osmotic pressure.

The osmotic effect is thus used to force the turbine to move. When the water is pressed out through the membranes a sucking effect, a stream appears. It is that stream, created by osmosis that makes the turbine spin. Thus, in neither of these plants osmosis is used for the direct generation of electric power. It is the sucking effect, the flow, which generates electric power.
Economic aspects

Due to the fact, that the material we have is old, it is hard to give an estimate of the cost of osmotic-produced electricity with any accuracy. And another difficulty in determine the costs is the large variety of cost estimates for reverse osmosis. Reverse osmosis is when you make fresh water out of seawater, also known as desalination.

Osmotic inc. gave a rough estimate for the cost of the membranes in 1977. This amounted to about $0,20/m² if 2km² of membrane area were produced. The power output for 1 km² would, by 1977 amount to 1,62 MW. This number has been calculated from the values given by several tests on semipermeable membranes.

We don't know how much, or in which direction these price-estimates have changed since 1977, but we guess that the costs haven't changed so much, because there haven't been that much research in this area, since then. At least not what we have heard. We do know that Norway are doing some research now on how to use osmotic plants in their fjords, but this is new and classified, so we couldn't get any material from them.

To this, many other costs will appear, for instance, pumping costs, installing costs. According to a calculation made by a scientist an osmotic plant is estimated to cost about $36,000 per installed kilowatt. Our conclusion is, that osmotic power plants, is nothing to invest money in. At least not here in Sweden were the salt-concentration in the water is very low.

Pros and cons

There are many attractive features about using salt for power. A big advantage is that it is renewable. There is no risk what so ever to run out of salt because of osmotic produced power. (Salt-water evaporation leads to precipitation over land.) The process creating energy, does not consume the salt, it only utilises it to force water to move. Another
advantage is that osmotic-produced energy has a minimal environmental impact. It is a very "clean" process and this is of course a big plus. The amount of heat that occurs in the process would raise the temperature less than half a degree Celsius, which is not harmful to the marine organisms.

When we come to the disadvantages one big obstacle is the costs. Compared to other energy-producing processes osmotic energy is extremely expensive, about 36 times as expensive as a conventional power plant. There are also engineering problems to be overcome. It is difficult to build a large plant and lower it in the sea as deep as 110 meters, in the SHEOPP converter-case, and about 90 meters down in the ground, when it comes to the underground plant described earlier. Further there is a problem with the protection of the marine organisms from the turbine and other machinery.

**ABB Alstom Power prospects**

Is it advisable for ABB Alstom Power, to invest money in osmotic energy? ABB has knowledge in building turbines, and probably they can build the hydro-turbines, which the different plant types require. But as a result of the high installing costs, no one wants to buy osmotic produced power. In Sweden, the costs will rise because the Baltic Sea only contains brackish water, which means lower efficiency and therefore higher costs.

Our conclusion: it would not be advisable for ABB Alstom Power, to invest money in, and develop hydroturbines for the osmotic plants, since the osmotic produced power is too expensive for anyone to buy.

**Exploitation possibilities**

There are many possible ways to exploit the energy from salinity gradients. With each of the possibilities it seems as osmotic pressure will be crucial. Here are two brief descriptions of possible approaches:

- **Reverse Electrodialysis:** This process involves direct electrochemical conversion in dialytic cells. Dialytic cells use the potential found between solutions of different salt concentrations, which are separated by charged membranes. For instance, fresh water has, in general, 850 parts per million dissolved salt water. That is equal to a potential of 80 millivolts at the interface (the membrane). By putting many cells in series it is possible to create more power.

- **Vapour Pressure Differences:** Another approach is to build a device that can use the difference in vapour pressure between fresh water and salt water. The difference can be used to run a turbine. There are many limitations to this system, but there are advantages too. For example no membranes are required (in order to use the vapour pressure differences).

**Future prospects**

The possibility to use the salinity gradient in the ocean for power lies within the technology that needs to be developed. There are currently two hurdles to overcome, which includes the membrane water part and sunlight. If we could develop the membrane to use salt-water as fresh water and brine with a higher salt-concentration as the concentrated solution, then it would be more feasible to use salinity for power. Or, the vapour pressure technique could be further developed. However, the biggest hurdle that needs to be overcome is the cost. Salinity power is not economically feasible compared to fossil fuels.

Currently, more effort is being put into developing salt-gradient solar ponds for energy (where osmosis is used). Therefore in the world of salt, there is more potential in using salt from the solar ponds as opposed from the ocean. The salt percentage will be much higher, which will increase the osmotic head pressure and more energy can be extracted.

**Conclusion**
The conclusion we have reached during this project is that osmotic energy is not something we can use in the nearest future. The disadvantages, the obstacles, are too big to be overcome at the moment. The cleaning of the membranes and the cost are good examples of such obstacles. However in the future if the technology is further developed and the costs will decrease, osmotic energy might be an alternative to the energy sources we use today.

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