Reverse Osmosis Power Generation 'Osmotic Power, a New Renewable Energy Source'

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Abstract- **Unlike solar, wind, wave and other sources of renewable energy, osmotic power plants harness a source of energy that is constantly available--fresh water streams running into the sea--thereby enabling sustainable, renewable power plants that produce constant, uniform electricity, all day, every day.**

The world's first osmotic power plant officially opened in Norway, providing sustainable, renewable electricity generation 24/7.

Unlike solar, wind, wave and other sources of renewable energy, osmotic power plants harness a source of energy that is constantly available--fresh water streams running into the sea--thereby enabling sustainable, renewable power plants that produce constant, uniform electricity, all day, every day.

Osmotic power generation harnesses the chemical energy locked in the gradient between salt water and fresh water by using an osmosis process. Osmosis is a process by which water moves through a membrane which blocks other particles, which is how it is used to purify water. For osmotic power it works in reverse, with osmosis drawing fresh water through the membrane to mix with salty water, thereby increasing its pressure which can be harnessed to drive electricity turbines.

"The core process is a lot like desalination in reverse". In desalination we are separating fresh water from salt water, but in osmotic power we are combining fresh water with salt water.

The pressure exchanger works similarly to a heat exchanger, essentially transferring the increased pressure from the salty outflow from the osmosis membrane to the fresh-water diluted output so it can drive a turbine. Without the pressure exchanger, the efficiency of the process would be too low to create full-scale osmotic energy generators.

"The pressure exchanger transfers pressure from a high-pressure stream to a low-pressure stream with 98 percent efficiency." Energy Recovery's pressure exchanger devices are currently installed in desalination plants worldwide, where they serve a similar function in increasing the efficiency of the osmosis process. Desalination plants discharge water that has higher salt content than the original sea water, piping the fresh water produced into cities for drinking.

Osmotic power plants, on the other hand, discharge fresh water diluted with salt water in exactly the same proportions as would have happened naturally when the stream flowed into the sea anyway.

Researches/Plans are going on to build plants where fresh water is already dumping into the sea, but the output of desalination plants could also be used even more successfully, since their output is twice as salty as seawater, thereby doubling the energy generation capability, which is proportional to saltiness.

Index Terms- reverse osmosis, pressure exchangers, membrane.

INTRODUCTION

Even a calm sea contains a large amount of energy. Where fresh water and salt water meet this potential can be exploited through osmosis, for example where a river runs into the ocean, with a membrane dividing fresh and salt water, osmosis will make the fresh water mix with the salt water creating a surplus of water on the salty side. This flow of water can be used to produce power. The force of osmosis can raise the water 120 metres which is comparable to a huge waterfall.

REVERSE OSMOSIS

Osmosis is a natural process involving the flow of a concentrated solution across a semi-permeable membrane barrier. Consider a tank of pure water with a semi-permeable membrane dividing it into two sides. Pure water in contact with both sides of an ideal semi-permeable membrane at equal pressure and temperature has no net flow across the membrane because the chemical potential is equal on both sides. If a soluble salt is added on one side, the chemical potential of this salt solution is reduced. Osmotic flow from the pure water side across the membrane to

the salt solution side will occur until the equilibrium of chemical potential is restored {(Figure 1(a)}. In scientific terms, the two sides of the tank have a difference in their "chemical potentials," and the solution equalizes, by osmosis, its chemical potential throughout the system. Equilibrium occurs when the hydrostatic pressure differential resulting from the volume changes on both sides is equal to the osmotic pressure. The osmotic pressure is a solution property proportional to the salt concentration and independent of the membrane.

With the tank in Figure 1(a), the water moves to the salty side of the membrane until equilibrium is achieved. Application of an external pressure to the salt solution side equal to the osmotic pressure will also cause equilibrium {Figure 1(b)}. Additional pressure will raise the chemical potential of the water in the salt solution and cause a solvent flow to the pure waterside, because it now has a lower chemical potential. This phenomenon is called Reverse Osmosis.

Reverse osmosis is most commonly known for its use in drinking water purification from seawater, removing the salt and other substances from the water molecules. This is the reverse of the normal osmosis process, in which the solvent naturally moves from an area of low solute concentration, through a membrane, to an area of high solute concentration. The movement of a pure solvent to equalize solute concentrations on each side of a membrane generates a pressure and this is the "osmotic pressure." Applying an external pressure to reverse the natural flow of pure solvent, thus, is reverse osmosis.

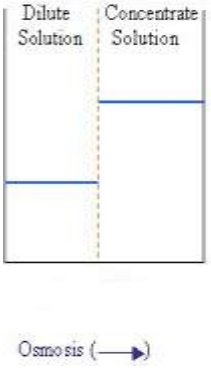

Fig.1(a)

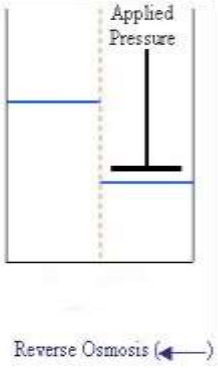

Fig.1 (b)

Reverse Osmosis (RO) is a modern process technology to purify water for a wide range of applications, including semiconductors, food processing, biotechnology, pharmaceuticals, power generation, seawater desalting, and municipal drinking water.

Salt is good for power generation, when salt and fresh water mix, we can generate clean energy.

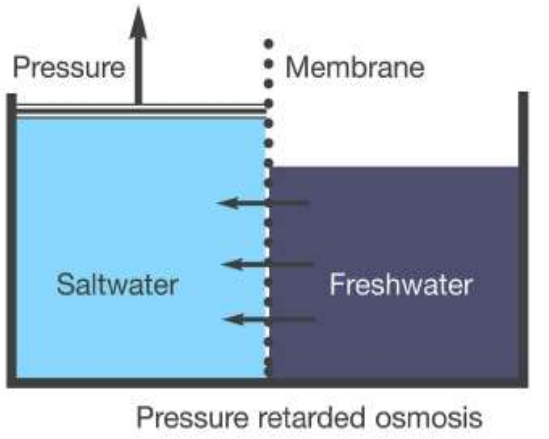

Fig. 2 (a)

Salinity gradient energy is based on using the resources of “osmotic pressure difference between fresh water and sea water.” All energy that is proposed to use salinity gradient technology relies on the evaporation to separate water from salt. Osmotic pressure is the "chemical potential of concentrated and dilute solutions of salt". When looking at relations between high osmotic pressure and low, solutions with higher concentrations of salt have higher pressure.

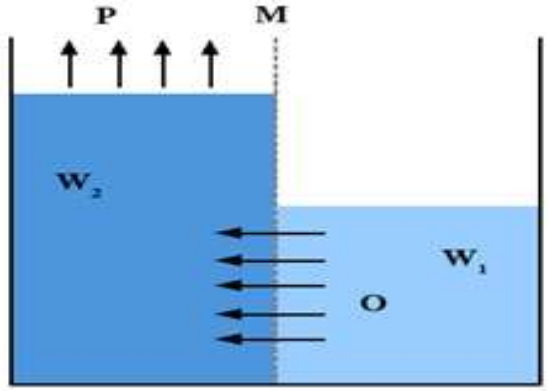

Fig. 2 (b)

Differing salinity gradient power generations exist but one of the most commonly discussed is Pressure Retarded Osmosis (PRO). Within PRO seawater is pumped into a pressure chamber where the pressure is lower than the difference between fresh and salt water pressure. Fresh water moves in a semipermeable membrane and increases its volume in the chamber. As the pressure in the chamber is

compensated a turbine spins to generate electricity. In Braun's article he states that this process is easy to understand in a more broken down manner. Two solutions, A being salt water and B being fresh water are separated by a membrane. He states "only water molecules can pass the semipermeable membrane. As a result of the osmotic pressure difference between both solutions, the water from solution B thus will diffuse through the membrane in order to dilute the solution". The pressure drives the turbines and power the generator that produces the electrical energy.

HISTORY (1970s idea)

The idea to generate power through osmosis originates from the 1970s. But back then the membranes were not sufficiently effective and the apower prices were too low to enable anyone to profitably invest in such projects. The world's first prototype of an osmotic power plant on the banks of the Oslo fjord is built in Norway. The project is small-scale but could prove the great potential of osmotic energy.

In recent years, the osmotic power concept has been tested in small pilot facilities, including in a laboratory at Norway. On 24 November 2009, Company named Statkraft opened the world's first prototype osmotic power plant at Tofte, southwest of Oslo. Statkraft has invested more than NOK 100 million towards development of osmotic power, with more to come.

RO Power Generation Process

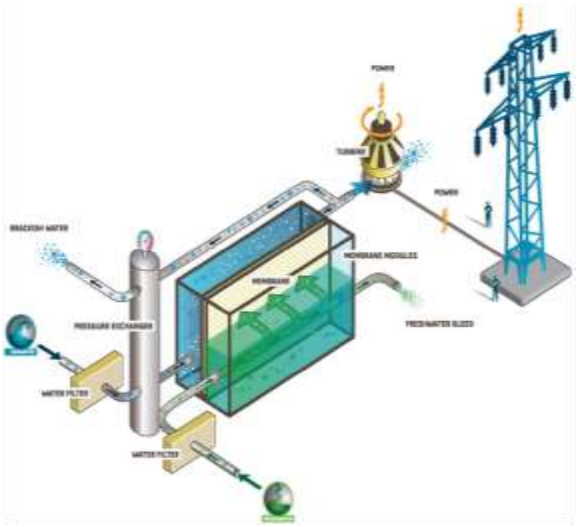

Fig. 3-From salt to Electricity

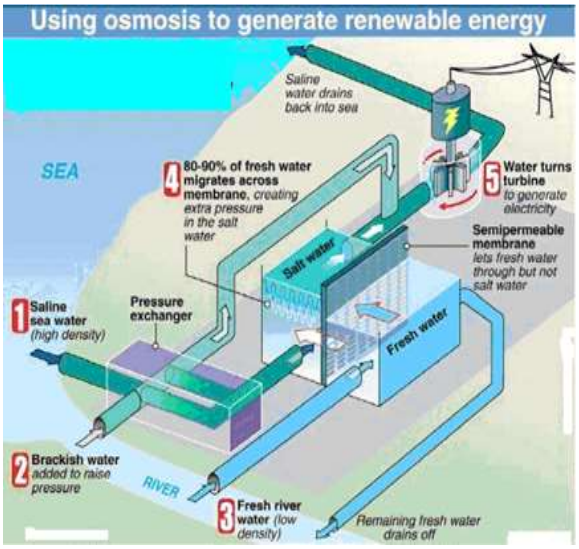

Fig. 4- RO Power Generation Process

RO TECHNOLOGY

Osmotic power or salinity gradient power is the energy retrieved from the difference in the salt concentration between seawater and river water. Two practical methods for this are reverse electrolysis (RED) and pressure retarded osmosis (PRO).

Both processes rely on osmosis with ion specific membranes. The key waste product is brackish water. This by product is the result of natural forces that are being harnessed: the flow of fresh water into seas that are made up of salt water.

The technologies have been confirmed in laboratory conditions. They are being developed into commercial use in the Netherlands (RED) and Norway (PRO). The cost of the membrane has been an obstacle. A new, cheap membrane, based on an electrically modified polyethylene plastic, made it fit for potential commercial use.

Other methods have been proposed and are currently under development. Among them, a method based on electric double-layer capacitor technology and a method based on vapor pressure difference.

The world's first osmotic plant with capacity of 4 kW was opened by Stat Kraft on 24 November 2009 in Tofte, Norway. This plant uses polyimide as a membrane, and is able to produce 1W/m² of membrane. This amount of power is obtained at 10 L of water flowing through the membrane per second, and at a pressure of 10 bar. Both the increasing of the

pressure as well as the flow rate of the water would make it possible to increase the power output.

Reverse osmosis (RO) is a filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective," this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely.

The membranes used for reverse osmosis have a dense barrier layer in the polymer matrix where most separation occurs. In most cases, the membrane is designed to allow only water to pass through this dense layer, while preventing the passage of solutes (such as salt ions). This process requires that a high pressure be exerted on the high concentration side of the membrane, usually 2–17 bar (30–250 psi) for fresh and brackish water, and 40–70 bar (600–1000 psi) for seawater, which has around 24 bar (350 psi) natural osmotic pressure that must be overcome.

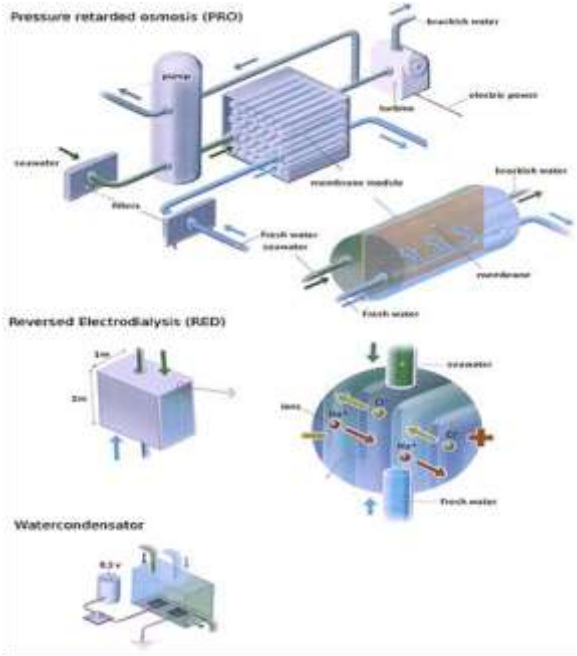

Fig. 5-RO Technology (Pressure Retarded Osmosis)

Osmosis describes how solvent moves between two solutions separated by a semipermeable membrane to reduce concentration differences between the solutions. When two solutions with different concentrations of a solute are mixed, the total amount of solutes in the two solutions will be equally distributed in the total amount of solvent from the two solutions. Instead of mixing the two solutions together, they can be put in two compartments where they are separated from each other by a semipermeable membrane. The semipermeable membrane does not allow the solutes to move from one compartment to the other, but allows the solvent to move. Since equilibrium cannot be achieved by the movement of solutes from the compartment with high solute concentration to the one with low solute concentration, it is instead achieved by the movement of the solvent from areas of low solute concentration to areas of high solute concentration. When the solvent moves away from low concentration areas, it causes these areas to become more concentrated. On the other side, when the solvent moves into areas of high concentration, solute concentration will decrease. This process is termed osmosis. The tendency for solvent to flow through the membrane can be expressed as "osmotic pressure", since it is analogous to flow caused by a pressure differential. Osmosis is an example of diffusion.

In reverse osmosis, in a similar setup as that in osmosis, pressure is applied to the compartment with high concentration. In this case, there are two forces influencing the movement of water: the pressure caused by the difference in solute concentration between the two compartments (the osmotic pressure) and the externally applied pressure.

CONCLUSION

It is a form of renewable energy which, unlike solar or wind power, produces a predictable and stable amount of energy regardless of the weather. Osmotic power could contribute around 1,600 TWh on a global basis annually. In some countries osmotic power has the potential to cover 10 percent of the total power consumption. Research points out that osmotic power plant give off no polluting discharges to the atmosphere or water, and that they do not affect the fauna or flora of rivers or the seafloor. Around the world, rivers flow out into the sea in urban and industrial areas where it will be possible to construct osmotic power plants. A power plant the size of a football stadium could supply around 10,000 households with electricity. These power plants can be built underground, e.g. in the basement of an

industrial building or under a park, minimising their visual impact.

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