ISSN 2229-5518

Osmotic Power
Huge Source of Renewable Energy

Avinash Mishra

Abstract— The need for renewable energy resources has never been bigger then today. A relative unknown, renewable energy resource is osmosis. It's based on the materials striving after equality. The potential resource for the osmotic pairing of fresh water and seawater is estimated at 2.6 TW. Several concepts have been proposed. Obviously, any scheme to desalinate seawater can be operated in reverse. Recent developments in pressure retarded osmosis; vapor compression, reverse dialysis and hydrocratic generation are highlighted. There are different types of osmosis power plant. Both land-based plants and plants anchored to the sea floor. Commercial barriers prevent necessary investment. The power available in salinity gradients will be exploited, but not without substantial investment.

Index Terms— Renewable Energy , Osmotic Power , Salinity gradient power , Pressure Retarded osmosis

I. Introduction

Energy drives the global economy. Global consumption of energy is growing at an astonishing rate. The US Department of Energy projects an increase of 60% in worldwide total energy consumption from 1999 to 2020. Accompanying this forecast is a 20-year increase in carbon dioxide emissions (60% increases above 1999 levels) as the world's population increases from 6.0 to 7.5 billion people.

While the United States with 5% of the world's population generates 30% of the world GDP, consumes 25% of the world's energy and emits 25% of the world's CO_2, it is believed the developing countries with their thirst for energy will drive the energy demand over the next two decades. Developing countries are projected to increase energy consumption by 3.8% per annum. Adjustment this projection to a more realistic level of 2% per annum is the consensus among energy industry analysts.

India ranks sixth in world so far as total energy is concerned, but still much more energy is needed to keep pace with our economic development objectives. Most of our energy requirements are met through fossil fuel that leads to dependence on imports and energy insecurity.

Avinash Mishra

Electrical Engineer , India ,
Email : avinash.spce14@gmail.com

Going by the statistics and forecast released by Ministry of power (India), the per capita power consumption has increased from 15.6 kWh in 1950 to 580 kWh in 2006. Further it is projected to increase to 932 kWh by 2012. The demand has risen to 39.26% as compared to earlier average increase of 10.74%.

Thus looking to the current scenario of India , it is forcing us to seek a source of energy which can help us to ramp up the production of electricity to a level that can satisfy our need of energy and increase our rate of development ,but now it has

also become necessary to explore the new form of energy which are more clean and safe as compare to the traditional use of fossil fuels which are getting depleted day by day and also not a cleaner source of energy.

II. Ocean Sources of Renewable Energy

Sources of marine renewable energy include ocean currents, ocean waves, tides, thermal gradients, and salinity gradients. Tidal energy relies on the gravitation attraction of the Earth- Moon-Sun system whereas the others all rely on solar energy. Prospects for the various energy sources including their power potential and energy density were assessed after the 197 3 energy crisis (see Table).

Resource	Power (TW)	Energy Density (m)
Ocean Waves	2.7	1.5
Tides	0.03	10
Thermal Gradient	2.0	210
Salinity Gradient	2.6	240

III. WHY OSMOTIC POWER

Osmotic Power is completely renewable and sustainable. Osmotic Power is the highest energy concentration (i.e., energy density, refer Table) of all marine renewable energy sources, an ultra-dense energy resource. It was recognized in the 1970s, that Osmotic power or "the energy represented by the salinity concentration gradient between fresh water and sea water" could be an attractive, large and untapped resource to explore.

In principal, there is no fuel cost. Salinity Gradient or osmotic power produces no CO2 emissions or other significant effluents that may interfere with global climate. Inefficient extraction would be acceptable as long as there is an adequate return on investment.

Depending on the technology chosen, systems could be non-periodic, unlike wind or wave power. Systems can be designed for large or small-scale plants and could be modular in layout.

The osmotic pressure difference between fresh water and seawater is equivalent to 240 m of hydraulic head. In theory, a stream flowing at 1 m3/s could produce 1MW of electricity. The worldwide fresh to seawater salinity resource is estimated at 2.6 TW comparable to the ocean thermal gradient (estimated at 2.7 TW).

Inland highly saline lakes (hypersaline) have an even greater potential. For example, the Dead Sea osmotic pressure differential corresponds to a head of 5,000 m (almost twenty times greater than seawater). Underground salt solutions or deposits have also been recognized.

Almost all of the proposed schemes rely on the fundamental natural process of evaporation to separate the fresh water from the salt.

A. Basics of Osmotic Power

Salinity gradient power or **osmotic power** is the energy retrieved from the difference in the salt concentration between seawater and river water. Osmotic Power is a specific renewable energy alternative that creates renewable and sustainable power by using naturally occurring processes. This practice does not contaminate or release CO2 emissions (vapor pressure methods will release dissolved air containing CO2 at low pressures-these non-condensable gases can be re-dissolved of course, but with an energy penalty). 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.

B. Methods to Utilize Osmotic Power

- Reverse Electro Dialysis (RED)
- Salinity Gradient Solar Pond
- **Pressure Retarded Osmosis (PRO)**

C. *Pressure retarded osmosis*

Pressure Retarded Osmosis (PRO) is a commonly used method for generating electrical energy.

Pressure retarded osmosis (PRO) is the salinity gradient energy retrieved from the difference in the salt concentration between seawater and river water. In PRO, the water potential between fresh water and sea water corresponds to a pressure of 26 bars. This pressure is equivalent to a column of water (hydraulic head) 270 meters high._However, the optimal working pressure is only half of this, 11 to 15 bars. In this method, seawater is pumped into a pressure chamber that is at a pressure lower than the difference between the pressures of saline water and fresh water. Freshwater is also pumped into the pressure chamber through a membrane, which increase both the volume and pressure of the chamber. As the pressure differences are compensated, a turbine is spun creating energy. This method is being specifically studied by a company in Norway called Statkraft, which has calculated that up to 25TWh/yr would be available from this process in Norway.

D. Working

The pressure retarded osmosis power plant is similar to a reverse osmosis desalination plant running backwards. However, the PRO plant generates power from freshwater in stead of consuming power.

A simplified PRO process diagram is shown at the end of this paper.

Freshwater is fed into the plant (grayish) and filtered before entering the membrane modules containing spiral wound or hollow fibre Membranes. In the membrane module, 80 – 90 % of the fresh water is transferred by osmosis across the membrane into the pressurized seawater (bluish). The osmotic process increases the volumetric flow of high pressure water and is the key energy transfer in the plant. This requires a membrane that has a high water flux and high salt retention. Typical membrane performance should be in the range of 4 – 6 W/m2. The brackish water (dark blue) from the membrane module is split in two flows. About 1/3 of the water goes to the turbine to generate power. 2/3 return to the pressure exchanger to pressurise the feed of seawater. To optimise the power plant the typical operating pressure is in the range of 11 – 15 bars. This is equivalent to a water head of 100 – 145 metres in a hydropower plant, generating about 1 MW/m3s freshwater. The freshwater feed operates at ambient pressure. Some pre-treatment of the water is necessary. Experience from Norwegian water treatment plants shows that mechanical filtration down to 50 um in combination with a standard cleaning and maintenance cycle is enough to sustain the membrane performance for 7 – 10 years. Similar lifetime data are assumed for osmotic power plants.

IV. PLANT DESIGNS

Several plant designs have been developed for PRO power generation.

A. Sea Level PRO Power Plant

A power plant based on this concept can look as illustrated at the end of this paper. Freshwater is taken from a river close to its outlet. Seawater is fed into the plant by underground pipes. The brackish water is let to the natural brackish water zone of the estuary thus maintaining the flow of water in the river. In many respects this PRO process can be designed as a run-of-river hydropower plant.

B. Sub-Sea PRO Power Plant

Another major concept utilizes the gravity in stead of the pressure exchanger to pressurize the incoming seawater. By placing the whole plant 100 to 130 metres below sea level the efficiency of the process can be increased significantly

The concept comprises a normal hydropower plant running on water from a river or a lake utilizing the extra water head. A membrane plant pumps the water out of the sub-sea cavern.

C. PRO Power Plant Below The Sea Level

Osmotic power can also be used for pumping of water across dikes, for example from IJsselmeer in the Netherlands to the North Sea. The flexible design of the PRO plant allows the combined power and pumping station (yellow) to be fitted between existing infrastructures as the illustration to the left suggests. The membrane section can preferably be located slightly below ground. Filtration units for saltwater and freshwater as well as turbine halls can be placed on appropriate locations in the area. This concept produces power at the same time as it drains the dyke. An additional advantage is that the water going into the ocean will be cleaner than the unprocessed freshwater.

V. ENVIRONMENTAL ASPECTS

A. POSITIVE ENVIRONMENTAL IMPACTS

- RIVER AND RIVER OUTLET:

  Interestingly, most rivers around the globe run into the ocean in a city or an industrial community. This means that most of the osmotic power potential can be utilized without constructing power plants in unspoiled areas. As discussed previously, the power plants can be constructed partly or completely under ground and would thus fit very well into the local environment. An environmental optimization and pre-environmental impact assessment of an osmotic power plant located at a river outlet has been conducted. As a conclusion; the possible negative environmental impacts can probably be compensated by a combination of environmental flow requirements for the river and the osmotic power plant and environmental engineering of intake and outlet of brackish water.

- WATER MANAGEMENT:

  The water management associated with the operation of the plant can be designed so that the biotopes of the river, estuary and sea are maintained in a healthy state. In some cases, particularly in heavily industrialized areas, it is possible that an osmotic power plant can improve the environmental conditions.

B. NEGATIVE ENVIRONMENTAL IMPACTS

There are at least two possible ways in which the use of this method of power production could harm the environment. One possible source of harm is indirect, and involves the use of polyethylene membranes. Another cause for concern is the impact of the brackish water waste on the local marine and river environment.

- EFFECT OF POLYETHYLENE:

  Polyethylene is a widely-used substance that is present in many of our everyday tasks. The plastic bags many people carry their groceries in are made from polyethylene plastics. It has been proposed that modified polyethylene membranes be employed in the process of extracting energy from the salinity gradients due to their cheap production cost and resulting commercial viability. The problem with this is that polyethylene is derived from crude oil, and the use of fossil fuel to produce materials for blue energy use seems counter-productive. Crude oil is converted to polyethylene by way of a process called "cracking", and two types of polyethylene can be produced in this way. Although this material can be recycled, it is usually discarded. Polyethylene does not easily biodegrade and is a major source of pollution. Discarded plastic bags and other packaging made from this substance has entangled marine animals and ingested by terrestrial fauna. In the spirit of not causing further environmental problems, it would be best to avoid supporting the production of polyethylene products or utilizing them in the production of blue energy.

- EFFECT ON MARINE LIFE:

  Marine and river environments have obvious differences in water quality, namely salinity. Each species of aquatic plant and animal is adapted to survive in either marine, brackish, or freshwater environments. There are species that can tolerate both, but these species usually thrive best in a specific water environment. The main waste product of salinity gradient technology is brackish water. The discharge of brackish water into the surrounding waters, if done in large quantities and with any regularity, may alter the aquatic environment significantly. Fluctuations in salinity will result in changes in the community of animals and plants living in that location. While some variation in salinity is usual, particularly where fresh water empties into an ocean or sea, these variations become more extreme on for both bodies of water with the addition of brackish waste waters. Extreme salinity changes in an aquatic environment may result in findings of low densities of both animals and plants due to intolerance of sudden severe salinity drops or spikes. The disappearance or multiplication of one or more aquatic organisms as a result of an influx of brackish water has the potential to cause ecosystem imbalance. The possibility of these negative affects should be considered by the operators of future large blue energy establishments.

VI. ADVANTAGES & DISADVANTAGES

- AREA EFFECTIVE ENERGY PRODUCTION:
  The osmotic power plant is very area efficient. A 25 MW plant would only require some 40 000 m2 of land even if it is located above the ground. Compared to a wind farm or the area required to harvest biomass to produce the same amount of energy, the osmotic power plant is very compact.

- BASE LOAD OPERATION:
  The investment cost for an osmotic power plant is relatively high per installed power compared with other renewable energy sources as for example wind or solar power. The main difference is that osmotic power plants will be designed for base load operation and are thus qualitatively different from most other new RE. This means that although a high investment per installed MW, the annual energy cost per kWh are comparable and competitive with the other RES. Although osmotic power development needs long term commitment the Salinity Power project represented a leap in the development of a potentially important future energy technology.

- PRICE FORECAST FOR RENEWABLE ENERGY:
  The forecast price level one can expect to achieve, included the green premium, will be 40-50 Euro/MWh in 2015. Present cost estimates made by the Statkraft show that osmotic power generation can be developed to be cost competitive with

renewable power sources such as bio power and tidal power when commercialized around 2015.

- EXPENSIVE COMPARED TO OTHER ENERGY SOURCES:

One big obstacle is the cost. Compared to other energy-producing processes osmotic energy is extremely expensive, about 36 times as expensive as a conventional power plant. This leads to increase in the capital cost.

- ENGINEERING PROBLEMS:

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 and about 90 meters down in the ground, when it comes to the underground plant described earlier.

- DISRUPTION TO MARINE LIFE:

Further there is a problem with the protection of the marine organisms from the turbine and other machinery.

- LESS DEVELOPMENT IN THE EQUIPMENT:

Equipment not yet developed to level of efficiency desirable. Hence this type of power plant cannot be used to fulfill the load with higher efficiency.

- PROBLEMS WITH THE MEMBRANE:
Energy costs for most technologies is quite sensitive to membrane efficiency and membrane costs, and in membrane systems, membranes are vulnerable to fouling. The cleaning of membrane ceases the generation process and also leads to high cost.

VII. CONCLUSION

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.

REFERENCE:

- Brochures
- MT Freshwater AB "Desalination with reverse osmosis" 1995
- Internet
- http://naring.regeringen.se/
- http://world-wide-water.com/index2.html
- http://taipan.nmsu.edu/aght/soils/soil_physics/tutorials/wp/wp_comp.html
- http://www-ib.berkeley.edu/IB/instruction/IB150/material/lectures/lecture22/
- http://edie.cprost.sfu.ca/~rhlogan/osmotic.html
- http://www.seas.ucla.edu/~sechurl/CP/sld001.htm
- www.ece.utep.edu
- www.statkraft.de
- www.wikipedi.com
- www.exergy.se

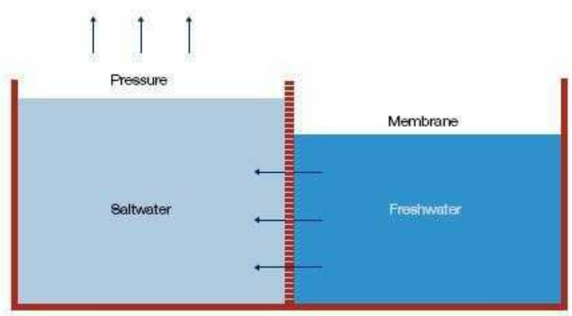
Literature

- National encyclopedia volume 14

AUTHOR :

Avinash Mishra
Electrical Engineer , India
avinash.spce14@gmail.com

Figures:



Pressure retarded osmosis