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Environmental, economic and performance merits of triple production of water, electricity and renewable energy

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ABSTRACT

The author had earlier proposed an Integrated Scheme for Seawater Desalination, Electricity & Renewal Alternative Fuel Production. This presentation, however, highlights Environmental, Economic & Performance Merits of the proposed scheme.

The scheme suggests the integration of Beach Well Intakes (BWI), Nano-Filtration (NF), i.e.; Selective ions separation with Pressure Exchanger Energy Recovery (PEER) devices, Solar Ponds Heat Generation (SPHG), Ammonia & Water Steam Turbine Generator (AWSTG), H_2O Electrolyzers (HOEL), Mixed Fuel Engined Vehicles (MFEV), Fuel Cell Engined Vehicles (FCEV), Hydrogen/ Oxygen Gas Turbine Generators (HOGTG), with AWSTG, i.e; Modified Combined Cycle (MCC), Multi Stage Flash (MSF) distillation, Seawater Reverse Osmosis (SWRO), Multi Effect Distillation (MED), Electro-Dialysis Reversal (EDR) and an Innovative Membrane Distillation (IMD) Process. The proposed desalination options are to be put into certain selective hybridization scheme based on site and demand specifics. Moreover, the scheme suggests inclusion of modified (low scaling potential) seawater, hydrogen, oxygen and product water storages plus hydrocarbon, hydrogen & oxygen filling as well as (combustion product pure) water collection stations for vehicles.

The article goes into verifying the merits of each system and how would their integration serve the objective of environmental, economic and performance merits of the scheme.

1. Introduction

The proposed concept comprises a number of processes and supporting systems. These systems are put together in an integrated fashion. The proposed integration is aimed at reducing consumptions of chemicals and mined fuel i.e.; non-renewable resources.

Thus environmental impact on the marine habitat is reduced, in order to protect most valuable food source of plant earth. On the other hand aerial discharge of contaminating gases will also be reduced especially Carbon, Nitrogen and Sulphur oxides. As these oxides are the primary causes of acid rain and Global Warming.

Mined fuel reduction as proposed in this concept would be achieved through shifting to solar heat harvesting. The concept calls for utilization of solar ponds to capture heat to be transferred to Ammonia or Ammonia/ Water mixture; that can be utilized as a steam turbine working fluids.

Consequently, the generated cheap electricity is to power modified seawater electrolyzers for the production of cheap Hydrogen and Oxygen. Environmental impact is further reduced by routing electrolyzers effluent brine to solar ponds rather than being discharged.

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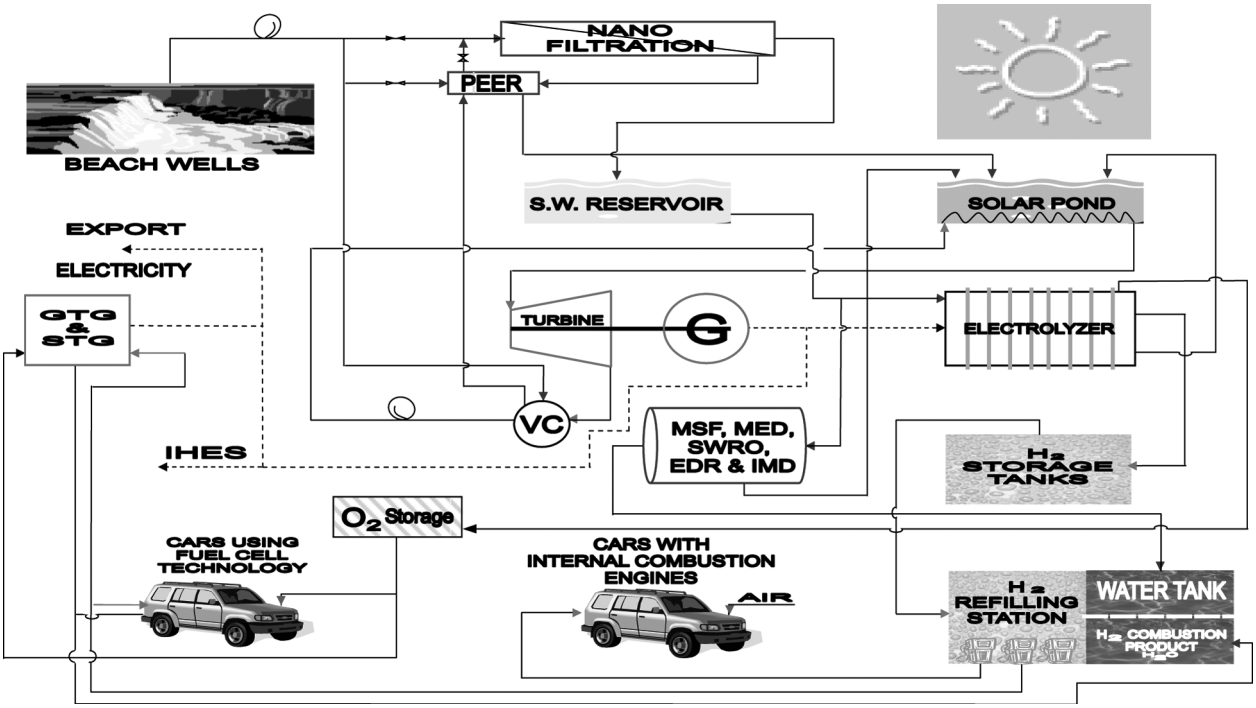

Fig. 1. Integrated production of water, power & renewable Energy.

The generated Hydrogen and Oxygen are to be stored for their combustion either in mixed or fuel cell vehicles. They could also be directly routed to gas turbine combustion chamber. The product of the later two combustion options would be Hydrogen Oxide, i.e.; pure water which can be routed to storage.

Likewise, turbine exhaust gas (in this case pure steam) is to be routed without the need for Heat Recovery Steam Generators (HRSG) to Back Pressure Steam Turbine generator (BPSTG).

Further down the stream, back pressure turbine low to medium pressure steam is to be routed directly to the thermal side of a proposed hybrid desalination of Nano Filtration (NF), Sea Water Reverse Osmosis (SWRO) with Multi Stage Flash (MSF) and/or Multi Effect Vapor Re-Compression Distillers (MED).

It is also worth noting here that the proposed concept calls for NF treatment of electrolyzers feed, SWRO as well as MSF make-up and/or MED feed; thus reducing scale control chemical requirements; hence, their discharge impact on marine environment. Moreover, the concept calls for desalination effluent brine routing to solar ponds, to further reduce discharges and thus thermal and chemical impacts on marine environment.

Likewise, for aesthetic and marine protection the concept calls for beach well sea water intakes.

2. Discussion

Fig. 1, shows proposed systems and the manner in which they are to be integrated.

This concept calls for integration of the following systems:

1. Beach wells;
2. Selective separation membrane;
3. Modified sea water storage;
4. Solar Heat;
5. Solar ponds;
6. Ammonia water steam turbines,
7. H_2O electrolyzers;
8. Hydrogen & oxygen storages;
9. Filling & collection stations;
10. Water storage;
11. Mixed fuel combustion engined vehicles;
12. Fuel cell engined vehicles;
13. H_2/O_2 gas turbine generator (HO GTG);
14. Ammonia/ Water, steam turbine generators (AW STG); and
15. Desalination processes:

    (a) Multi stage flash (MSF)
    (b) See water reverse osmosis (SWRO)
    (c) Multi effect distillation process (MED)
    (d) Electro-dialysis reversal (EDR)
    (e) Membrane distillation process (MDP)

Primary objectives of integrating above systems are:

1. Development of environmentally friendly production schemes;
2. Reduction of process chemical and equipment costs;
3. Reduction of exploited non-renewable hydrocarbon fuel resources.
4. Improving process performance factors; and
5. Harvesting renewable (cheep) energy sources, e.g.; solar heat (in this case).

From this brief identification of objectives one can digress into further details of purposes for which each system is incorporated into this concept.

1. Beach Wells inclusion aimed at reducing marine environmental impacts of:
   (a) Damaging beach areas i.e.; restored aesthetic;
   (b) Marine habitat due to:
      (i) Civil and mechanical structures, and
      (ii) Chemical discharges;
2. Selective ion separation by Nano Filtration to reduce scaling potential and thus chemical requirements;
3. Storage of modified sea water for a steady operation of electrolyzers & desalination units;
4. Solar Heat as a cheap energy source;
5. Solar ponds to harvest solar heat;
6. Ammonia/Ammonia-water steam turbine generators to improve electrical power generation efficiency;
7. Water electrolyzers using cheap electricity to generate Hydrogen and Oxygen;
8. Hydrogen & Oxygen Storages for steady operation;
9. Filling and Collection Stations for gas refilling vehicles and to empty their water collection tanks of combustion product (off loading) H_2O i.e., pure water.
10. Water storage for routing water from collection stations, desalination plants and in certain cases from electrical power generation plants combustion product;
11. & 12. Mixed Fuel combustion engined vehicles as a transitional stage of conversion from hydro carbon internal combustion engines to the utilization fuel cell engine vehicles technology;
13. Hydrogen/Oxygen Gas Turbine generators (HO-GTG) for electricity production;
14. Hydrogen/Oxygen: Ammonia or Ammonia/Water Steam Turbine generators (HO:A,AW STG) for electricity production and heat supply to thermal desalination processes e.g.; MSF or MED as well as Membrane Distillation Process (MDP); and last yet quite vital would be:
15. Desalination processes of: MSF, SWRO, MED, EDR and/or MDP for water production.

It is also worth noting that as a step into improved electrolyzers and desalination process operations NF has been proposed as a feed treatment scheme.

The following table shows chemical analysis of various desalination process streams which clearly supports incorporation of NF as a selective ion separation process. The application of NF treatment is felt to be a breakthrough in desalination industry (Table 1).

Enhanced performance is a key objective, thus Fig. 2 is presented hereafter, as being the most dominant integrated dual production process. This figure shows what this dual production scheme comprises. That is sea water Desalination by MSF and Power Generation by BTG which are quite viable systems in any future integration as they had proven their abilities over many decades so far.

Table 1
Laboratory analysis of ionic concentration of various steams, using NF

Parameter	Unit	Sea water	NF product[a]	NF reject	SWRO product	SWRO reject
TDS	ppm	45.550	33.500	67235	780	61.410
Chloride ions	ppm[b]	23.838	19,497.50	31648	382	35,419.50
Sulfate ions	ppm	3.309	75	9129	ND	128
Calcium ions	ppm	491	154	1097	1	281
Magnesium ions	ppm	1.556	225	3951	2	406
Bi-carbonate ions	ppm	155.5	57	163	4	101.5
Total hardness $CaCO_3$	ppm	7,633	1,310	19,012	8–5	2,350
M-alkalinity	ppm	127	47	134	3	83

[a] NF stands for nano-filtration, i.e., selective separation membrane.
[b] ppm stands for parts per Million; i.e., milligram per Liter (mg/l).

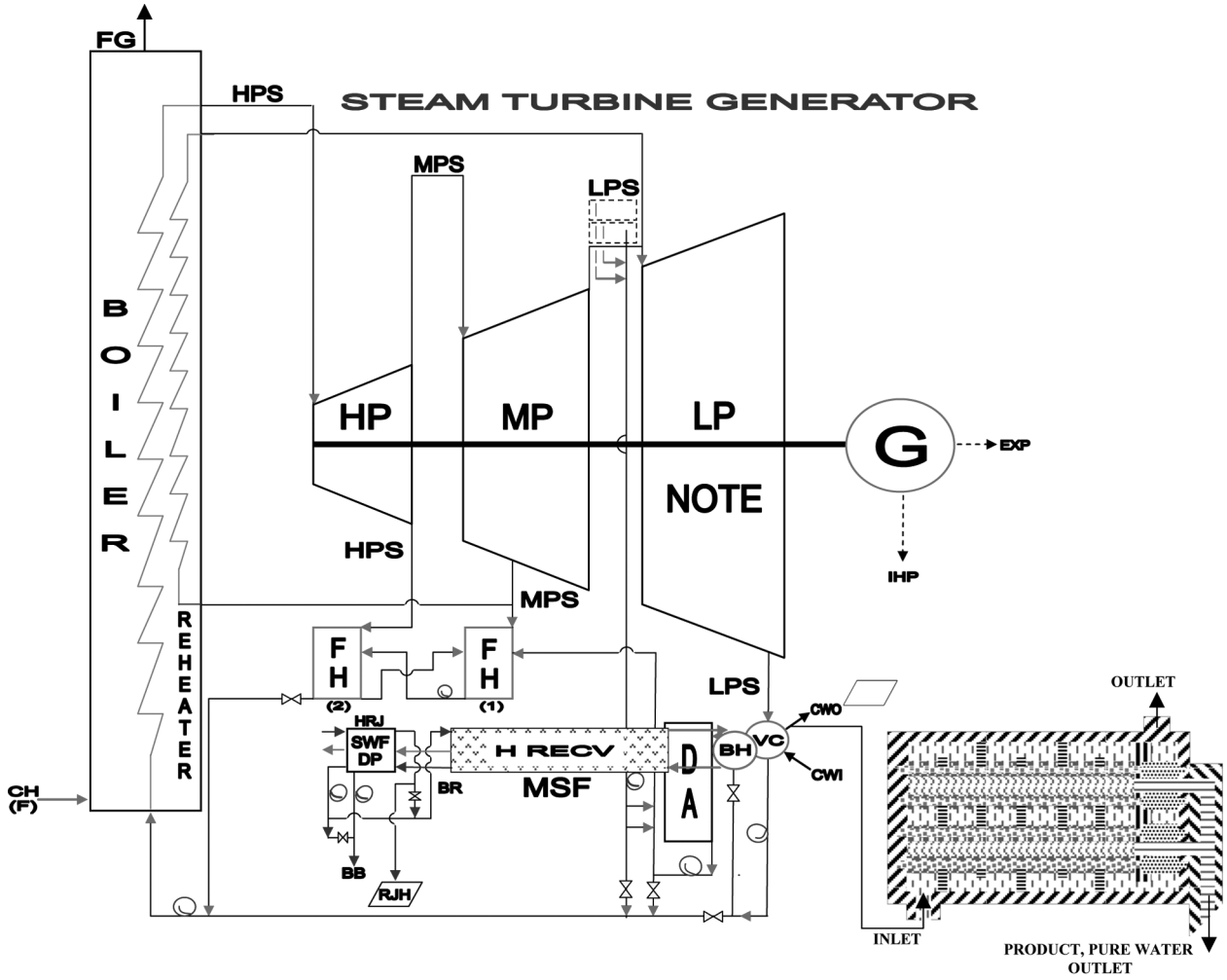

Fig. 2. Dual purpose water & power production (BTG-MSF).

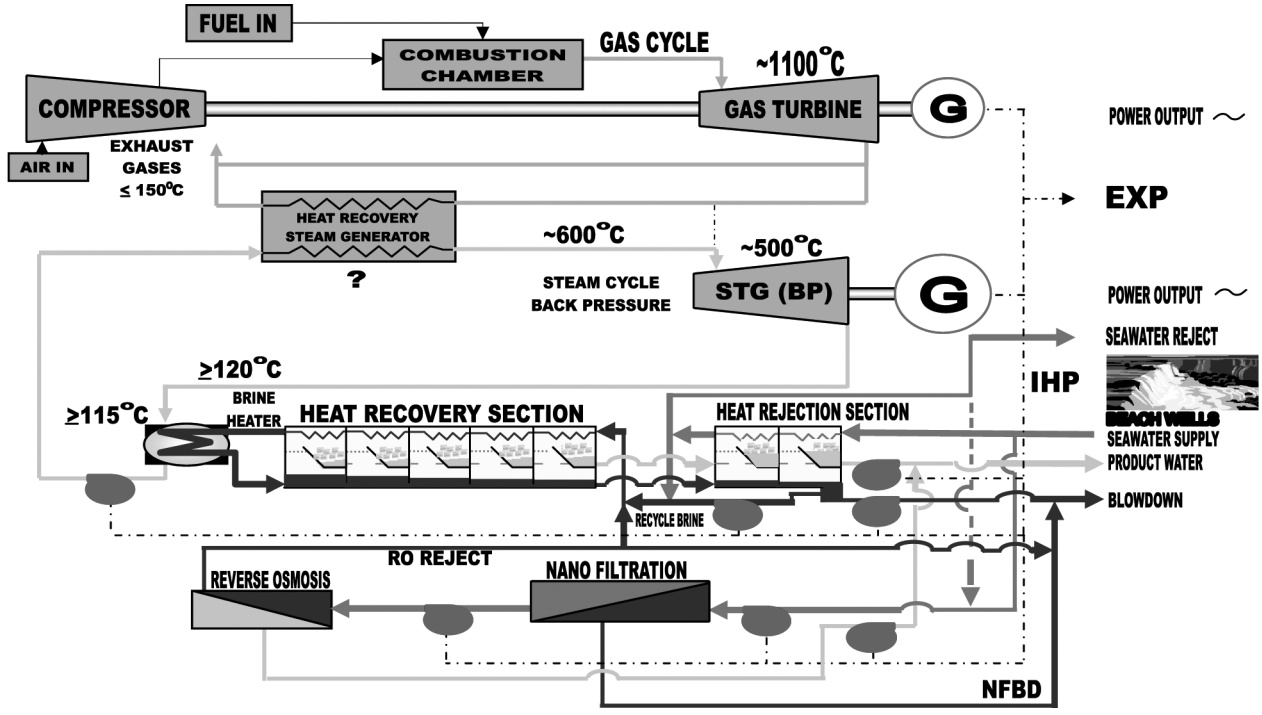

Fig. 3. Integrated production of water & power (Triple Twins – TT).

Further integration of water and power is shown in Fig. 3. This Figure Shows Hydrogen & Oxygen fed Gas Turbine Generator – GTG and/or Back Pressure Steam Turbine Generator – BPSTG with or Without Heat Recovery Steam Generator – HRSG as the case may be. That is to say that this twin electrical power production is found to positively contribute to the proposed integrated concept and thus it has been incorporated in Fig. 3. This Figure also shows couple of additional twin processes of sea water feed treatment and desalination. These in the same order, are beach well utilization and NF as well as SWRO & MSF. However, MSF could either be replaced or integrated with MED, like wise SWRO could be replaced and/or augmented with MDP.

As shown earlier NF had given way to further improve on MSF distillation. Thus this integration scheme also proposes adding a new section to conventional MSF design as it is known today. Fig. 4 shows this improvement, which is being called: Multi stage over flash evaporation – (MSOFE). MSOFE calls for expanding on temperature, pressure, salinity and production ranges of conventional MSF. Such expansions are felt to positively contribute as means of upgrading MSF so it would gain further economic attractiveness while maintaining its records making operational safety. This is primarily due to reduced scaling potential of brine solutions when either one or the combination of NF treated, i.e., modified sea water, and low scaling potential SWRO reject is (are) used as make up.

Multi effect distillation – MED is shown next in Fig. 5. It is worth noting here that MED (TVC) performance is Highly Influenced by Scale Formation thus the incorporation of NF would guarantee surpassing this limitation. Such improvement is due to reduced scaling potential as NF treated sea water would inter desalination processes after being depleted off calcium, Magnesium, Carbonates and more so Sulfate Ions.

In this respect it has been commonly known that upper temperature limit of MED had always led to scaling tubes externals. In other words MED had always been pledged with scale formation outside its tubes especially in higher tube rows of high temperature effects. Furthermore there were countable cases of hard scale deposition inside the ejector shell body.

For the sake of completeness Electro-Dialysis Reversal – EDR is shown in Fig. 6 below. And finally an Innovative Membrane Distillation-IMD i.e., Purr Vaporization Distillation-PVD is being proposed as shown schematically in Fig. 7. This scheme primarily depends on *Hydrophobic* nature of certain membranes, where liquid water stays away from its surface and thus with little heating of sea water feed; vapor is created and thence permeated through.

3. Concluding remarks

Finally some concluding remarks are made under three headings.

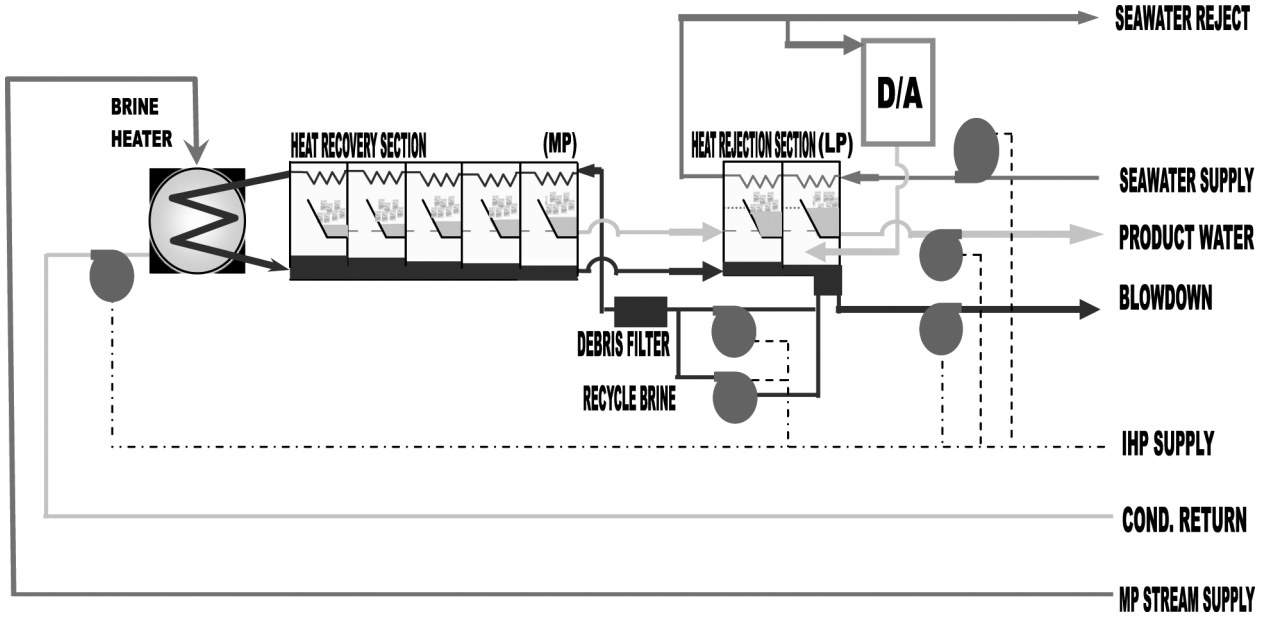

Fig. 4. Multi state over flash evaporation (MSOFE).

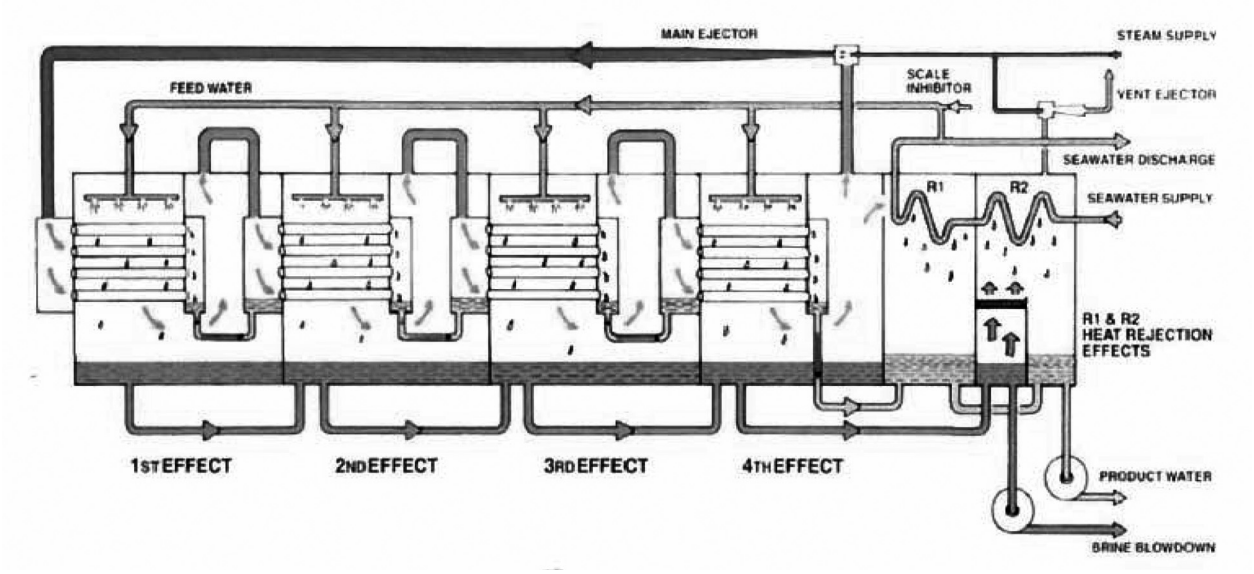

Fig. 5. Multi effect distillation (MED).

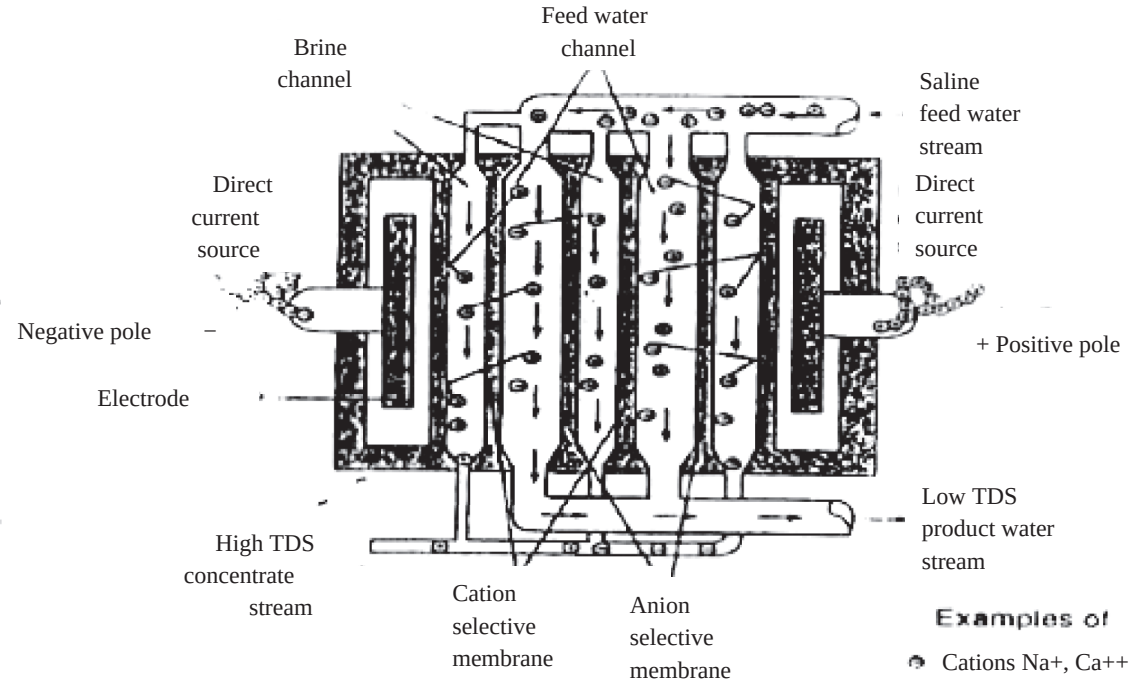

Fig. 6. Electro-dialysis reversal (EDR).

A) Economic & performance merits

1. Reduction of chemical usage due to reduced ingress of suspended matters;
2. Redundancy of mechanical separation equipment;
3. Reduction of scale formation prevention chemical dosing, due to reduced scale forming species;
4. Increased membrane recovery by 2–3% per 1 °C in colder seasons;

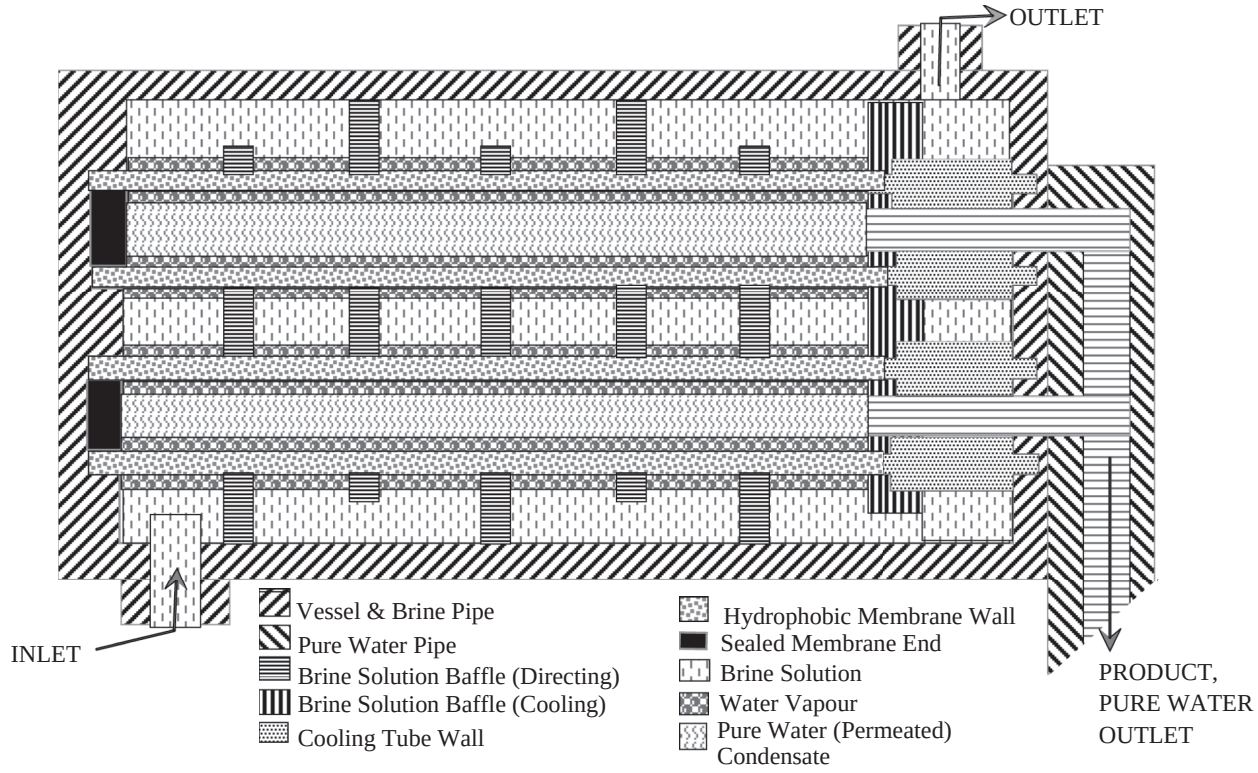

Fig. 7. Innovative (modified) membrane distillation (IMD).

5. Quantitative restoration of marine organisms due to reduced chemical content of limited and/or zero effluent discharges;
6. Renewable solar energy harvesting;
7. Production of oxygen & hydrogen as renewable alternative source of fuel;
8. Reduction of mined fuel resources;
9. Endorsement of promising innovative desalination processes in view of reduced scale forming species of Ca, Mg, Sulfate & Carbonates; and
10. Water (H2O) production as a result of H2 combustion with O2.

B) Environmental merit

1. Qualitative restoration of marine organisms due to reduced chemical contents of limited and/or zero effluent discharges;
2. Reduced impact on Natural Habitat of Wildlife and Plants of Land and Sea due to reduced exploration, drilling and mining;
3. Increased arial humidification (i.e., reduced dryness-though minute) due to hot water evaporation in solar ponds as a result of routing hot rejects & solar heat;
4. Reduction of Sulfur and Nitrogen Oxides emissions, thus reduction of pollution & acid rains; and
5. Reduction of carbon dioxide emissions, thus reduction of pollution and green house effect, Thence restoration of ocean levels and reduced ice caps melting especially of South and North Poles.

C) Closing notes

The proposed concept is felt to deserve financial and administrative support, where the first is needed to generously fund research and development towards commercialization of the concept. Thereafter the administrative support is to be directed towards qualifying and promoting the concept for future projects.