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RESEARCH ARTICLE

TECHNO ECONOMIC EVALUATION OF A SOLAR POWERED ENERGY SYSTEM FOR POWERING REVERSE OSMOSIS

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ABSTRACT

Drinking water is the essential need for human beings, but most of the land mass is occupied by sea water which is salty in nature and contains lot of contaminants which must be purified in order for it to be consumable by living beings. There is huge scarcity for energy for purification of water and energy demands of human beings are ever increasing. In this scenario for day to day requirements energy is required for water purification, so powering a reverse osmosis system using renewable energy for producing fresh water is being considered as a viable option to meet such requirements. The techno economic evaluation of the small size reverse osmosis system has been presented in the following paper. All the renewable energies originate from Solar Energy, and the efficiency of Solar PV system is high when compared to other technologies, hence Solar PV technology in conjunction with reverse osmosis was considered the best option. In the present paper taking the climatic conditions of Bhopal in Central India, technical potential of such a project has been presented. HOMER software has been used to calculate the net present or Life cycle costs of the system and the comparison of all the costs has been presented. There is an additional advantage of using Renewable energy especially solar energy that the Carbon emissions can be reduced. Due to the increasing awareness among the countries to reduce the Carbon emissions, hence these technologies can earn carbon credits which are valuable assets for developing countries such as India. The results obtained clearly showed that even though the capital costs of a Solar PV system may be high but in the long run, it will give huge benefits. Due to the National Solar Mission, there is huge subsidies being provided for such systems, hence the entire future lies in harnessing these technologies.

INTRODUCTION

Water is the most essential commodity for all the purposes. The most essential requirement is for drinking purposes. There are plenty of water bodies available but which are not suitable for consumption purposes, so there is requirement for purification of water. Out of all the technologies reverse osmosis is the most promising technology. Due to the depletion of fossil fuels there is everywhere energy scarcity. Water purification is day to day requirement, so there is requirement of an energy source which is available in plenty. Renewable technologies exactly cater to such need, as they are available in plenty, especially in Bhopal, Central India, Solar and Wind energy is available in plenty as it is clear from the software also. So combination of such renewable energy with reverse Osmosis Technology seems to be most promising area for research and upcoming field of study. In the current study all the water purification technologies which can be used with Renewable energy has been discussed. All the possible combinations of the sources of energy have been taken and most optimized combination has been found using the software. HOMER software program developed by U.S. National Renewable Energy Laboratory [1] calculates the optimized combination based on Net Present Cost or Life Cycle Cost of the System. Apart from the results obtained from the software the initiatives taken up by the government are also very significant in choosing the combination. The National Solar Mission [2] also gives lot of subsidies for installing Solar Power plants.

TECHNOLOGICAL COMBINATIONS

There are various technological combinations of integration of Renewable energy with water purification processes. According to Mathioulakis [3] the possible combinations have been classified depending on the Renewable energy used with desalination technologies. The figure1 clearly describes the technological combinations.

According to them they have classified they have classified the renewable energies into Geothermal, Solar and Wind. But when it comes to Indian Conditions Geo thermal can be potentially only used for cooling purposes, it is not so efficient system. So basically it comes down to either solar, wind or combination of them. The technology to be chosen depends on the local climatic conditions and the potential of that renewable energy at that place. Before using the software to

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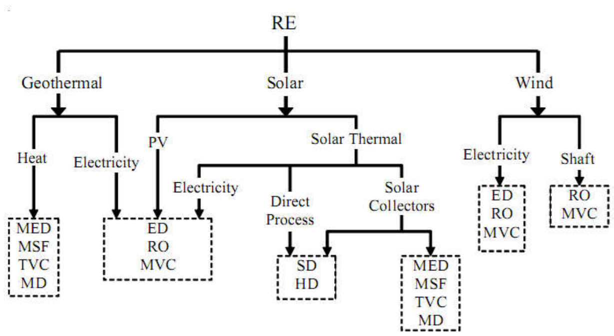

Fig1. Technological Combinations of Conjunction of Renewable Energy with Water Purification Technologies

find the technologically optimized combination, one can select type of energy depending on the form of energy. As it clear from the figure that Solar energy can be classified into two

a. Solar PV
b. Solar Thermal

Out of two technologies Solar PV technology is more efficient as it directly converts Solar energy into Electricity which is high grade energy, whereas the later from converts into thermal or heat energy which is low grade energy and it has to directly used or again converted into electrical energy. Wind energy can be converted into electrical form or can be used in the form of mechanical energy; the loss is more when used as mechanical energy. So it is clear from the above that either Solar PV or Wind energy in the form of electrical energy can possibly be the most optimized combination.

Table1. Nomenclature of the Methodologies used

College	Abbreviation
MED	Multi Effect Distillation
MSF	Multi Stage Flashing
MVC	Mechanical Vapor Compression
MD	Membrane Distillation
ED	Electro Dialysis
RO	Reverse Osmosis
SD	Solar Distillation
HD	Humidification-Dehumidification

1. RO system

According to Efthiazen [4] Reverse Osmosis is the most suitable combination and 62% of total water purification technologies in conjunction with the Renewable energy has been using Reverse Osmosis Technology. So RO desalination system has been considered for the following design. In Reverse Osmosis water is filtered with the help of membranes. There are various types of Reverse Osmosis System. An example of such reverse Osmosis System has been shown in the figure2.

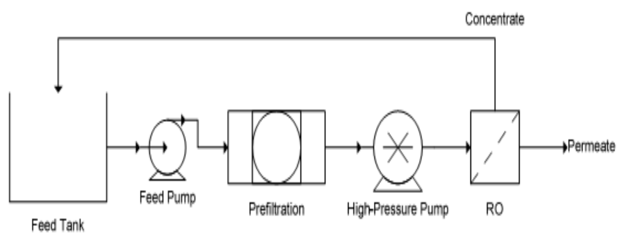

Fig. 2. Schematic diagram of an RO desalination unit

There is lot of water requirement as input for reverse Osmosis System, hence water must be stored or collected in a feed tank. This water is fed into prefiltration unit with the help of feed pump, feed pump is a low pressure pump which is just used to pump the water into the prefiltartion unit. Prefiltration unit is basically consists of filters such as activated Carbon, Activated Carbon removes the basic impurities such that the water can be fed into RO unit. By using prefiltration one is expanding the Life of RO membranes as fouling does not occur very early because of less wear and tear. Then after prefiltration water is pumped with a high pressure using a high pressure pump into the RO unit, The quality of the Output of the Reverse Osmosis System depends on the pressure with which water is pumped into the system. Typically a RO Sytem comes with two to four membranes depending on the capacity. For Domestic Applications generally a small RO which is giving 8- 10 Liters output per hour is used. After the Reverse Osmosis Filtration, permeate can be used for drinking purposes mostly, else it can be post treated to meet the drinking water standards and the concentrate can be again fed into the feed tank. The refeeding of the concentrate is only for improving the efficiency of the system, it is not necessary, depending on the requirement it is done.

Design of PV-RO system

The procedure for designing PV-RO system has been given by A.Chel and G.N.Tiwari[5]

Selecting the Number of hours of usage of RO system

For the current design, a 48W RO pump as given by the manufacturer is taken into consideration, this 48W pump is high pressure pump which feeds water to the membrane assembly, this system runs for 6 hours in a day.

Determination of design electrical load

The electrical load of the system (E) = 48*6= 288Wh. (1)
But considering higher value in case of overload,
So designing for fifry percent overload (L) =1.5*288=432Wh (2)

Determination of number of sunshine hours for the location

The number of sunshine hours in India varies from 4 to 5 h/day from[5]. The optimum tilted angel for PV array for particular location is equal to latitude of that place [5]

Determination of PV array size (W_p)

The PV array size is determined using Eq. (3)

PV array size required(W_p) =

$$\frac{Design\ Electrical\ load(E)}{Number\ of\ sunshine\ hours} = \frac{432}{4} = 108\ \text{W} \quad (3)$$

Number of PV modules (N) =

$$\frac{\text{PV Array Size } (W_p)}{\text{Peak watt of PV module}(W_p)} = \frac{108}{38} \cong 3$$

(4)

Total Watt Power = 38*3=114W

The PV modules are available in the market in various sizes and of various types, the typical range for peak watt of Solar PV panels are 35/75/150 W_p. In the present study 38 W_p PV module is being considered for the PV array design since it was available in Department of Energy, MANIT, Bhopal and the operating voltage was decided to be 12V. Generally voltages used in Solar PV array and battery bank are of the ranges 12/24/48 V.

Determination of inverter size(W) and charge controller capacity(A)

The inverter rating should be always more than the PV array rating. The capacity of the inverter rating (W) should be atleast 10% higher than the PV array size for safe and efficient operation of PV power system [5]. Hence, the inverter size can be determined using Eq.(5). The charge controller capacity can be determined based on the PV array size and system voltage requried

Inverter capacity(W)=1.1* PV array size(W_p)
Inverter capacity = 1.1*114 =125 W
Charge controller capacity(A) =

$$\frac{\text{PV Array Size }(W_p)}{\text{Battery bank design voltage(V)}} = \frac{114}{12} \cong 10\,A \qquad (5)$$

Determination of battery bank size(Ah)

Battery Bank size can be determined either in Ah or in Wh. The Battery Bank size in terms of (Ah) is given by

Battery bank size (Ah) =

$$Autonomy\ days * \frac{\text{Design Electrical load(E)}}{\text{Battery Voltage}} = 1 * \frac{432}{12} = 36\text{ Ah} \qquad (6)$$

Since for the present case autonomy days was taken to be one

PV-RO system analysis

1. HOMER Simulation

The present simulation was done for smaller system so as to prove the efficacy of this project for smaller cases.

2. Site parameters

The selected site is Bhopal in Central India; it has latitude of 23 degrees to the North and Latitude of 77 degrees towards east. The Time zone of the place is +5:30 hours. HOMER automatically gives the solar potential of the place. As we give the Latitude and longitude of the place, it gives the Solar Potential of the place. Wind data can be found by using RETSCREEN software [6]. The Wind data and Solar Data of the place are shown in the figure [3a and 3b] and figure [4a and 4b]. Apart from the monthly radiation data, HOMER also gives the clearness index of the place. Clearness Index of the place is indicator, of the clearness of the sky, so it is an indirect indicator for the Solar radiation of the place. The best fit for the Wind data was found to be with Weibull parameters of k=1.96 and c=3.68 m/s. The methodology for input data was given as given by Nema [7]. In this software the input data is nothing but the initial Costs of the System, Replacement Cost of the System and operation and maintenance cost of the System.

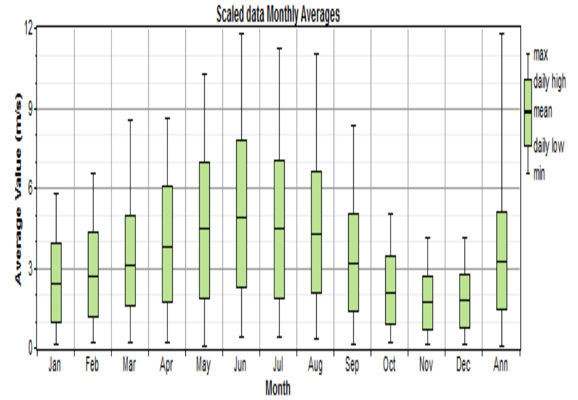

Fig. 3a

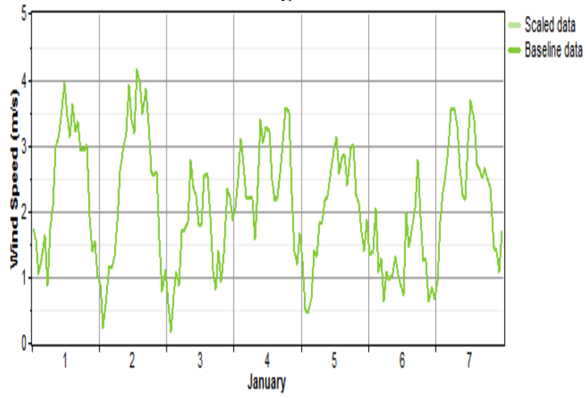

Fig. 3b. Wind resource Data

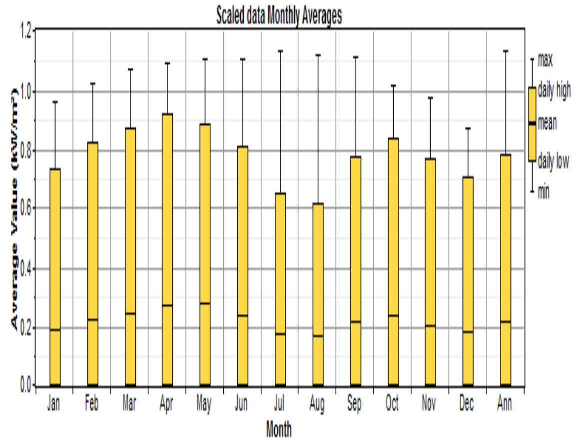

Fig. 4a

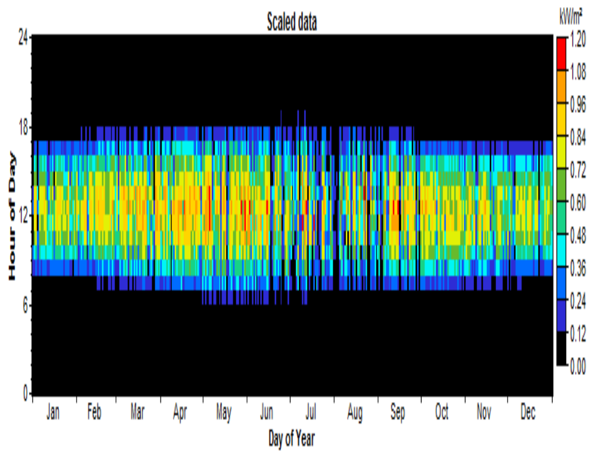

Fig. 4b. Solar resource Data

3. Simulation results

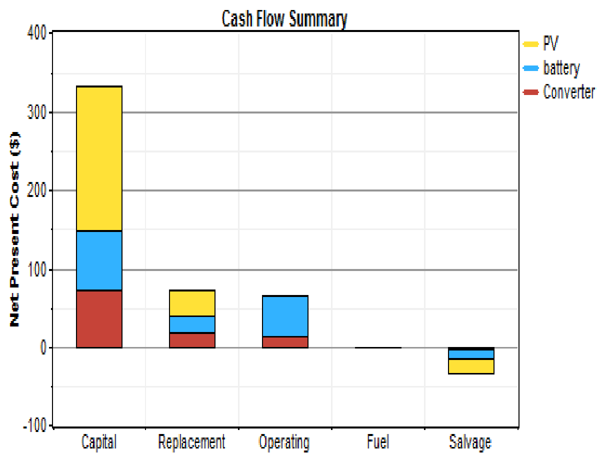

Fig 5. Cash flow summary

Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	116
Carbon monoxide	0.285
Unburned hydocarbons	0.0316
Particulate matter	0.0215
Sulfur dioxide	0.232
Nitrogen oxides	2.55

Fig 6. Emission reduction

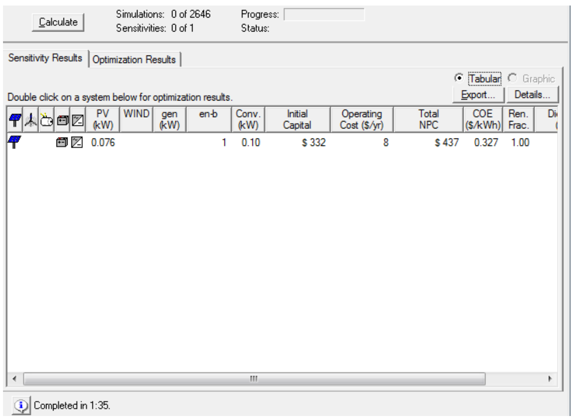

Fig 7. Optimization Results

As per the simulation results it has been clear that the optimal configuration is that which has Solar PV alone with converter and inverter. The renewable energy fraction in this case is 1 which is very high. The optimization has been done based on Net present value which is nothing but Life cycle cost of the system. The mitigation potential of the project has also been shown. As shown in the figure a reduction of 116 kg per year of carbon dioxide for such a small configuration which is huge amount considering the system. The Cash flow Summary and the Emission reduction potential has also been shown.

Conclusion

Thus the technical viability of the method adopted has been assessed both theoretically and practically through the software. It is clear from the Literature also that the current system of method is best applicable. To substantiate the results HOMER software was used. As it can be seen that though the initial Cost of generator System may be less but due to the very low operating Cost, the Life Cycle Cost of the System is very less, hence such configurations can be implemented in very large scale. In the Current Study validation of the method chosen was done for a small system to show the efficacy of the System. The results clearly indicate the Efficacy of the System and technical, economic viability of the system

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