Hybrid Power Supplies to Water Desalination Units for Remote Areas in Iraq

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Abstract

Hybrid systems utilizing renewable energy and conventional diesel generators are important sources for the supply of electricity for remote areas away from the electricity grid. To maximize the use of the renewable energy source, the size and operation of the hybrid system components need to be matched to the load and the available renewable resources. The software (HybridRO), which is suitable for the examination of several types of power supply systems using renewable and conventional energy sources for an RO desalination unit, was used to simulate the performance of a hybrid power-supply system to provide the required power to a Reverse Osmosis (RO) desalination plant and calculates the unit cost of water produced. Three types of energy supply were considered, namely diesel, wind and solar in addition to all possible combinations of these sources. The evaluation of each scenario was based on number of parameters that included, but not limited to, the unit cost of desalted water, capital cost and payback period of the unit and the amount of diesel fuel consumed. A small community in Iraq with 1000 inhabitants was chosen in this study as an example of the small communities that depend on ground water for providing drinking and other essential water needs. Meteorological data such as solar radiation intensity, ambient temperature and wind speed for Iraq were used in the simulation. An average daily demand per person of around 100 liters, which is equivalent to around 100 cubic meters per day, was allocated. The study concluded that the lowest water cost is 1.8 $/m3 for RO unit powered by either an 8-kW diesel generator or by a combination of diesel, wind and solar power. Relying on renewable energy as the only source increase the water cost to 2.0-2.3 $/m3 depending on the source type. A significant reduction in the fuel burned occurred with the introduction of the renewable energy sources. The annual consumption of fuel was reduced from 23.87 tons for RO-diesel unit to only 4.55 tons for a diesel, wind and solar combination with no increase in the water cost. The choice of a solely renewable energy supply, solar or a combination of wind and solar was concluded to be the most reasonable choice for remote areas in Iraq at the present situation due to the difficulty in providing and transporting the fuel required to run the diesel generator.

Keywords: Desalination; Hybrid power; Renewable energy; Iraq

Introduction

Water is essential for maintaining the life of human beings, for agriculture, producing food and for maintaining our health and dignity. Many large and small communities in Iraq are suffering an acute shortage of drinking water that meets minimum health requirements. A recent United Nations Development Programme study found that more than 722 000 Iraqi families have no access to either safe or stable drinking water, a full 70 to 76% of all rural households find difficulties in obtaining the drinking water they need. Many remote areas in Iraq are characterized by a lack of both water and energy where no grid electricity is available. Ground water is the main domestic water supply in these areas. Supplying water and energy to such areas to improve quality of life and enhance economic development is an important issue.

Hybrid systems utilizing renewable energy and conventional diesel generators are important sources for the supply of electricity for remote areas away from the electricity grid. In some cases, this is the most economical option, since long-distance grid extensions are very expensive. To maximize the use of the renewable energy source, the size and operation of the hybrid system components need to be matched to the load and the available renewable resources. Reverse osmosis (RO) is known to be the most economical process available today because of recent developments in the technology and lower energy requirements compared to the thermal processes. Due to its modular nature, this process is suitable for all plant capacities.

Many simulation software models have been developed for desalination systems [1-7]. A simulation program generally predicts the performance of a chosen system, which may be a single system or combination of more than one system comprising photovoltaic, wind turbines, diesel generator, battery storage, etc. The analysis of the simulation results provides an understanding of the most appropriate technology to meet the load and to utilize in optimum way the power resource of a particular site. The selection of the power supply system is based first on the type of energy sources available, followed by the size and the control operation of the system components and their cost-effectiveness. Generally, these simulation models can be classified into two broad categories namely Logistic and Dynamic [1]. Logistic models are primarily used for; long-term performance predictions, system design and component sizing, studies of system operation and providing data for economic analyses. Dynamic models on the other hand are generally used for; component design, assessment of system stability and determination of power quality.

The Simulation Model Used

HybridRO [1] is software suitable for the examination of several types of power supply systems using renewable and conventional energy sources for an

RO desalination unit. It simulates the performance of a hybrid power-supply system, which provides the required power to a Reverse Osmosis (RO) desalination plant and calculates the unit cost of water produced. The power supply system must be able to cover the power requirements of the RO unit for producing the required quantity of water demand. This software is used in this study to evaluate seven power-supply scenarios to a Reverse Osmosis desalination unit in Iraq. Three types of energy supply are considered, namely diesel, wind and solar in addition to all possible combinations of these sources. Meteorological data such as solar radiation intensity, ambient temperature and wind speed are used in the simulation. The evaluation of each scenario is based on number of parameters that include, but not limited to, the unit cost of desalted water, capital cost and payback period of the unit and the amount of diesel fuel consumed.

A small community in Iraq with 1000 inhabitants is chosen in this study as an example of the small communities that depend on ground water for providing drinking and other essential water needs. There are large numbers of wells in Iraq; their water is exploited for agricultural and drinking purposes. Salinity of water supplied from many of these wells is around 6600 ppm. An average daily demand per person of around 100 liters, which is equivalent to around 100 cubic meters per day, is allocated.

Results and Discussion

1.1 Power Supply Scenarios

Considering the potential power sources namely wind, solar and diesel, the possible scenarios for the RO unit power supply are:

- Diesel
- Wind
- Solar
- Diesel + Solar
- Diesel + Wind
- Diesel + Solar + Wind
- Wind + Solar

The simulation reveals that an 8-kW diesel unit is capable of providing the full power to the RO unit required to meet the water load (100 m^3/day). Accordingly, the diesel contribution is kept at this level in the diesel-participated scenarios. In the solar-wind combinations, the contribution of each may vary and several combinations are possible; however, a cost-effective contribution of each is sought in the simulations.

1.2 Unit Water Cost

The unit cost of desalted water for the seven power-supply scenarios from annual simulations are given in Table 1 and plotted in Fig. 1. The lower water cost is found to be 1.8 $/$m^3$ for RO unit powered by either an 8-kW Diesel generator or by a combination of Diesel, Wind and Solar power. Relying on renewable energy as the only source would result in an increase in the water cost to 2.2 $/m^3$ for Solar, and to 2.3 $/m^3$ for Wind. Although the cost of wind energy is known to be more competitive with conventional energy sources than solar, this is only true, however, for locations with wind speed greater than 7 m/s in general (the wind speed in the area in question is 5 m/s). A better option than using just Wind or Solar powers would be the combination of both, as this option will reduce the size of the wind generator and hence the cost of water to 2.0 $/m^3$. Another attractive option, with a cost of 1.8 $/m^3$, is to use Solar or Wind with Diesel.

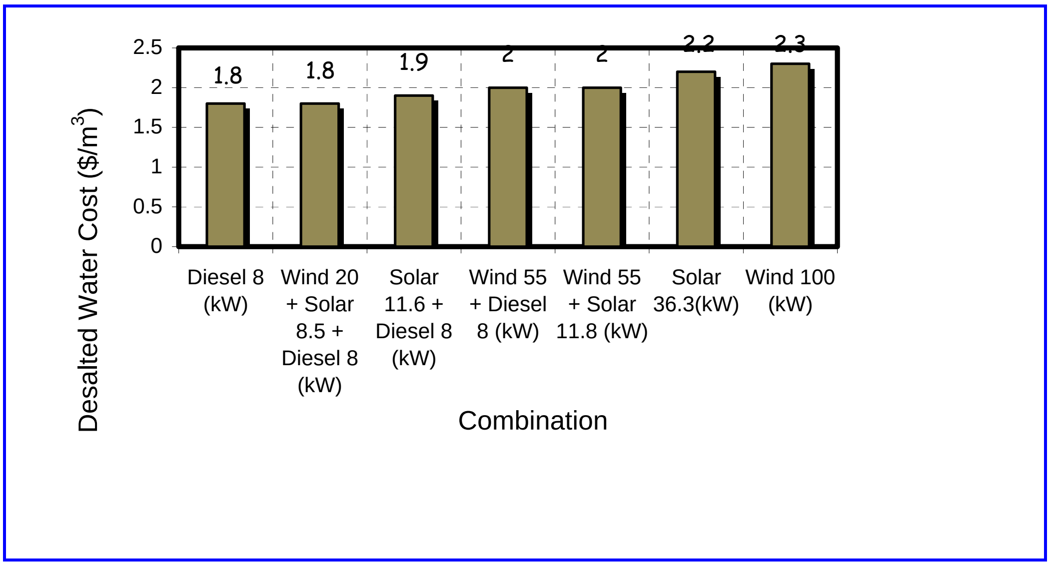

Fig. 1 Unit water cost for the various power scenarios

1.3 Payback Period and Capital Cost

The unit water cost and the payback period for each scenario are shown in Table 1 and plotted in Fig. 2. The payback period for the various scenarios shows a maximum difference of around 2 years, and that is between the diesel and solely renewable (wind and solar) scenarios. In general, the introduction of a renewable energy source or increase its share will increase the payback period, obviously due to its higher cost compared to diesel generators. It can be seen from Table 1 and Fig. 3 that the capital cost of a diesel-RO unit is $491000 compared to $657000 for the cheapest solely renewable (solar)-RO unit and $643000 for a diesel-renewable (solar) RO unit. It is well known that the capital cost of the renewable energy technology is higher than that of the diesel generator. The difference however, may be compensated by the advantages of renewable energy such as eliminating the need for fuel transportation and routine maintenance to the diesel generator.

1.4 Amount of Diesel Fuel Burned

The amount of fuel burned by the diesel unit and the unit water cost for the 8-kW diesel-participated combination is shown in Fig. 4. A great reduction in the fuel burned can be noticed with the introduction of the renewable energy sources. One interesting case is that of the diesel, wind and solar combination where the amount of fuel burned is reduced from 23.87 tons for RO-diesel unit to only 4.55 tons with no increase in the water cost. Relying on the renewable energy sources solely will obviously eliminate the need for fuel but it will increase the water cost by 0.2 to 0.5 $/m^3$ compared to the RO-diesel unit (from 1.8 $/m^3$ to 2.0 or 2.3 $/m^3$ depending on the renewable energy source(s) used).

Table 1 - Unit cost of desalted water, capital cost, payback period and the amount of diesel fuel burned for the various power scenarios

Combination	Wind (kW)	Solar (kW)	Diesel (kW)	Water Cost ($/m^3)	Capital Cost (1000 $)	Payback (years)	Diesel Fuel Burned (ton)
Wind	100			2.3	736	8.7	
Solar		36.3		2.2	657	8.2	
Diesel			8	1.8	491	7.1	23.87
Wind + Solar	55	11.8		2.0	679	9.2	
Wind + Diesel	55		8	2.0	627	8.7	1.61
Solar + Diesel		11.6	8	1.9	543	7.5	13.56
Wind + Solar + Diesel	20	8.5	8	1.8	579	8.5	4.55

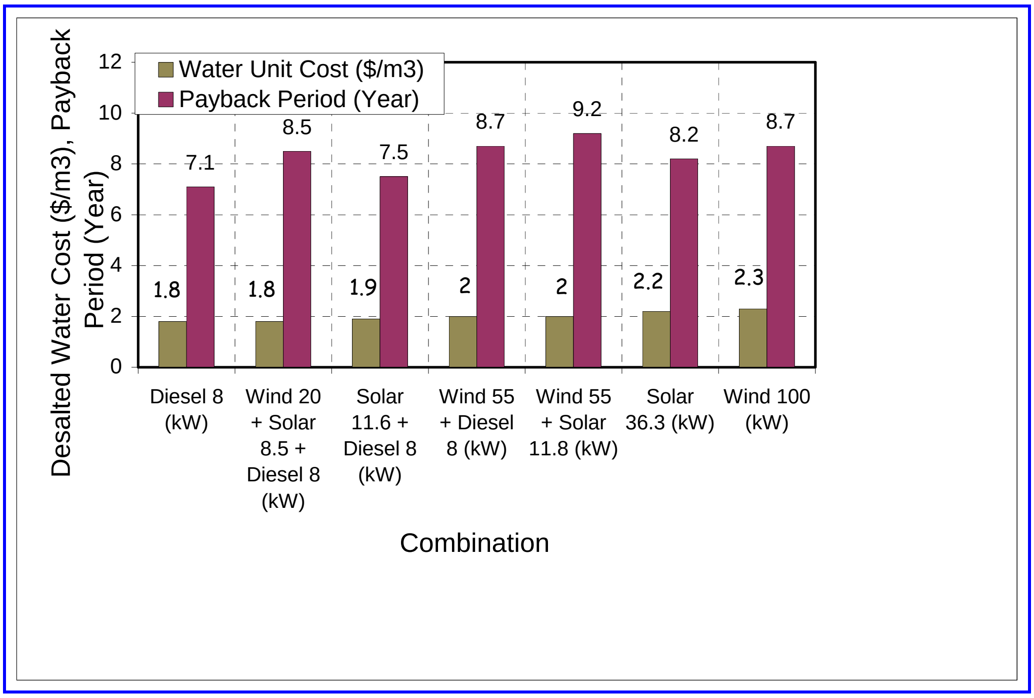

Fig. 2 Unit water cost and payback period for the various power scenarios

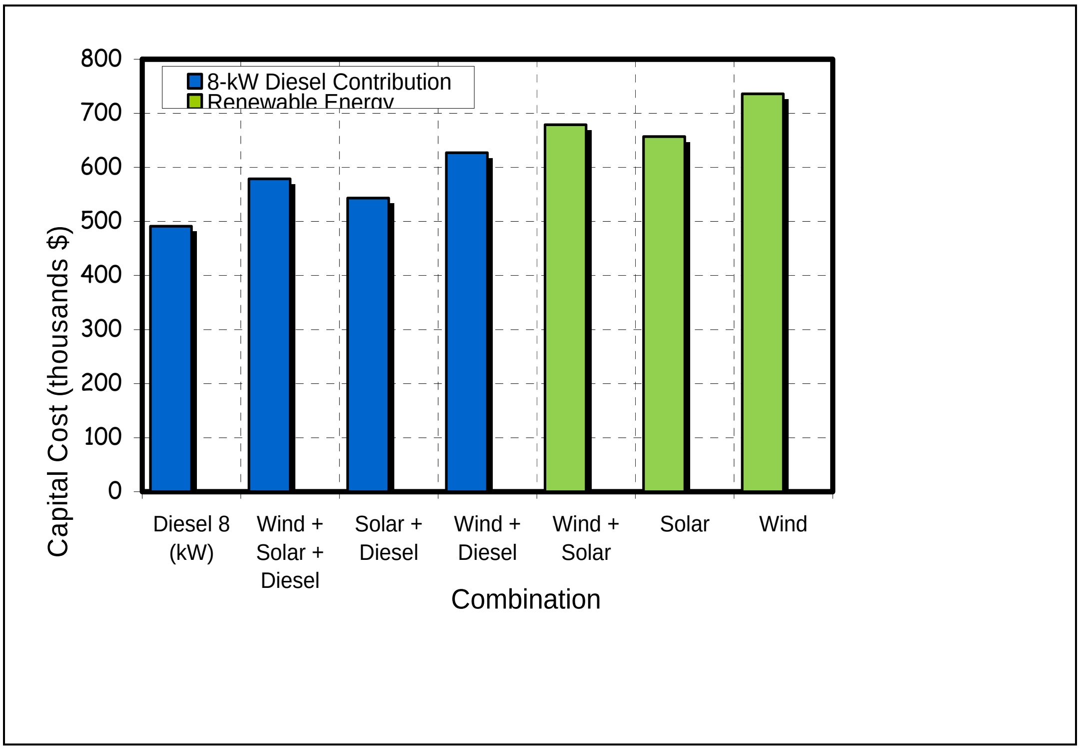

Fig. 3 Capital cost for the various power scenarios

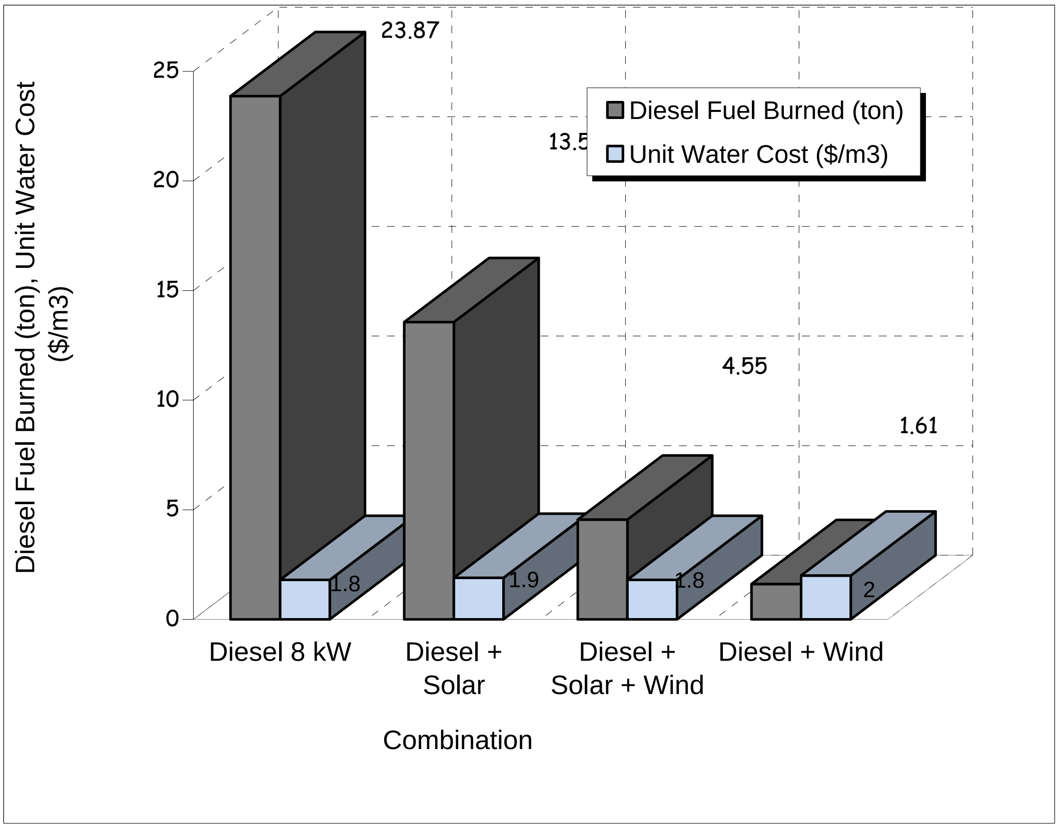

Fig. 4 Amount of fuel burned and unit water cost for the diesel participated scenarios

1.5 Which Scenario Should We Choose?

The following are found to be the main parameters that may be considered in choosing a certain power supply scenario from the seven scenarios that have been simulated:

- Unit cost of desalted water.
- Capital cost of the desalination unit.
- Payback period of the desalination unit.
- Amount of diesel fuel burned by the diesel unit.
- Local constrains such as fuel availability and transport issues, maintenance, and availability of skilled workers...etc.

The main possible alternatives are:

i. From a financial point of view, the best choice would be the one with the minimum cost of unit-desalted water, minimum capital cost and minimum payback period.

ii. If environmental and financial considerations were to be taken into account, the best choice would be the one that compromise between the cost and the amount of burned fuel.

iii. From environmental point of view, the best choice would by solely renewable energy source(s) that yield the minimum water cost.

By examining the results, the following are the three potential choices:

i. The best cost-effective choice would by an 8-kW diesel power supply with the lowest cost of desalted water of 1.8 $/m^3$.
ii. The choice which compromises between the financial and environmental aspects is a wind, solar and diesel combination with an equal water cost to that of the previous option of 1.8 $/m^3$ and with a great reduction in the amount of fuel burned yet with higher capital cost and payback period.
iii. Choosing a power supply for a desalination unit in Iraq requires the additional consideration of local constrains, such as the availability of fuel and the difficulty in its transportation to remote areas. Despite Iraq has the second largest confirmed oil reserve in the world, it is hard to get fuel. Consequently, the choice of a solely renewable energy supply, solar or a combination of both wind and solar, would be the most reasonable one, especially at the present situation.

Conclusions

A computer simulation is used to examine seven power-supply scenarios to a Reverse Osmosis desalination unit. Three types of energy supply are considered, namely diesel, wind, solar and all possible combinations of these sources. The unit is to provide a small community of 1000 inhabitants in Iraq with 100 litres per day per person with a total daily capacity of 100 m^3. The evaluation of each scenario is based on a number of parameters that are obtained from the simulation namely, the unit cost of desalted water, the capital cost and the payback period of the unit and the amount of diesel fuel burned.

The following conclusions may be drawn from this study:

1. The lower water cost is found to be 1.8 $/m^3$ for RO unit powered by either an 8-kW diesel generator or by a combination of diesel, wind and solar power.
2. Relying on renewable energy as the only source would result in an increase in the water cost to 2.0 $/m^3$ for solar-wind combination, to 2.2 $/m^3$ for solely solar, and to 2.3 $/m^3$ for solely wind.
3. Reducing the share of diesel energy would generally cause an increase in the water cost due to the increase in the share of the more expensive renewable energy.
4. The payback period for the various scenarios shows a maximum difference of around 2 years in favour of the diesel compared with solely renewable (wind-solar) scenarios.
5. The introduction of a renewable energy source or increase its share will increase the payback period, due to its higher cost compared to diesel generators.
6. The capital cost of a diesel-RO unit is found to be \$491000 compared to \$657000 for the cheapest solely renewable (solar)-RO unit and \$543000 for a diesel-renewable (solar) RO unit. The difference however, may be

compensated by the advantages of renewable energy such as eliminating the need for fuel transportation and routine maintenance of the diesel generator.

7. A great reduction in the fuel burned is noticed with the introduction of the renewable energy sources. For the diesel, wind and solar combination, the amount is reduced from 23.87 tons for RO-diesel unit to only 4.55 tons with no increase in water cost.
8. The choice of a solely renewable energy supply, solar or a combination of both wind and solar, would be the most reasonable one for Iraq at the present situation due to the difficulties in getting and transporting the fuel required for the diesel generator.

Acknowledgments

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