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Mutual adaptability of renewable energy and water-supply systems in islands

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Abstract

With the further development of the island regions and the development of the marine economy, solving the problem of energy and water scarcity of island area is becoming increasingly urgent and important. This paper summarizes and analyzes the existing mode of water and energy supply system in many islands of the world, and then tried to do a preliminary analysis of the island energy systems coupled with water system, based on which a framework of island's energy and water systems was proposed. The new framework reveals a trend for the renewable energy and water-supply system from "Full Input of Energy & Water (FIEW)" to "Semi-Input of Energy & Water (SIEW)" again to "Zero Input of Energy & Water (ZIEW) ". As a case study, the renewable energy-driven water-supply system in Maldives was analyzed, and summarized its potential problems. The results show that the ZIEW (Zero Input of Energy & Water) system can be implemented in Maldives in the future, and it would be the principal direction of future energy and water-supply system in island regions.

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Keywords: Renewable energy; Water resources; Energy and water-supply system; Island, Mutual adaptability

1. Introduction

There are more than 50,000 islands in the world, which accounts for 17% of the total land area of the world[1], and more than 700 million people live on them, accounting for about 10% of global population [2]. Island economy has become an indispensable part of the global economy [3],but the important strategic resources of energy and water resources are usually sparsely in island regions for its special natural and geographical environment, and severely restrict island's economic and social development [4].Water and energy systems are in a close coupling relationship. Despite the lack of conventional energy and freshwater

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resources in island areas, they usually have plenty of sea water and renewable energy [5,6]. So it is worthy to address energy and water problems in island regions. Kuang, Y. [4] summarized the renewable energy utilization of the island area, he noted that the construction of efficient, reliable, affordable energy systems will be the development direction in the future for the island area. Solar power had been introduced as a primary energy supply, and a portion of solar power is used for desalination[7]. For renewable energy utilization of island, there are already a lot of mature technology applications precedent[8,9].

2. Island energy and water-supply

2.1 .Island energy supply

Currently the island's power supply is mainly carried out by two ways: submarine cables and diesel power generation, the former one is mainly applied to the island that lies not far away from the mainland, and the latter is a more universal way, but it needs to address the problem of fuel transporting. Taking account of the cost of the fuel itself and the cost of transportation, diesel power generation is very expensive in island regions[4]. In addition, the diesel generator generates noise and air pollution, which would damage the marine environment.

The island energy supply systems could be classified into three categories: the imported conventional energy supply system (ICESS); the imported conventional energy and renewable energy supply system (ICE&RESS); Integrated energy supply system (IESS).

2.2.Island water-supply

Lack of fresh water has become one of the most important factors that hinder the island area's economic and social development. The main features of water in island area are including three aspects:

- The rainfall is mainly frontal rain and typhoon rain, whose uncertainty is large;
- The streamflow is difficult to utilize for lack of storage facilities;
- The ground water is limited by poor groundwater storage conditions.

Island water-supply systems could also be classified into three categories: the imported water-supply system (ImWSS); the imported water and unconventional water-supply system (IW&UWSS); Integrated water-supply system (InWSS).

3. Coupling Analysis of island’s energy and water systems

3.1.Coupling framework of island’s energy and water systems

Water and energy have a very close relationship between each other[10]. In most islands, the conventional energy and freshwater resources are both lacking. But there are a lot of renewable energy and sea water that can be used as potential energy and water-supply. Figure 1 shows the coupled framework of island’s energy and water systems.

3.2.Renewable energy-driven water-supply system

Renewable energy-driven water-supply system is the development trend of fresh-water system in islands. It is evolved from fossil energy-driven water-supply systems. In the future, the new system will not rely on fossil energy and will be zero-input of freshwater, so called “Zero Input of Energy & Water (ZIEW) " system. The new system will pass three stages of development: full input type, semi input type and zero input type, and it shows in Figure 2.

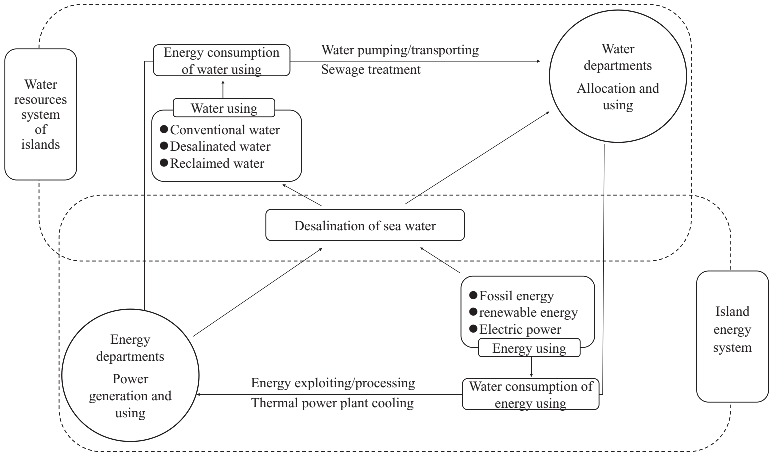

Figure .1 . Coupled framework of energy and water-supply systems in islands

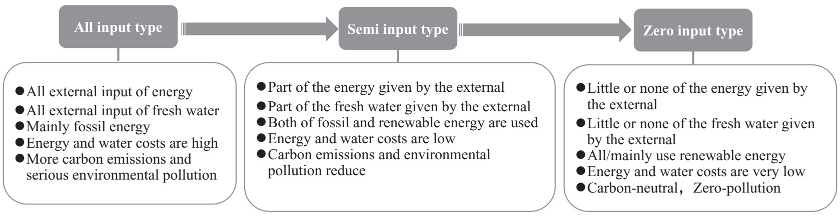

Figure .2. Three stages of energy and freshwater systems development

3.3. Matching analysis island's energy and water

The island's demand of energy and water in the mainland is estimated, the results shows in table 1.

Table 1 Daily demand of energy and water per capita

Type of energy demand	Amount (kW·h /d)	Type of water demand	Amount (L /d)
ghting	0.3	Drinking	2
Cooking	1.3	Cooking	8
Traveling	0.5	Shower	20
TV	0.4	Flushing	6
Refrigerator	0.8	Food and vegetable	18
Computer	0.3	Municipals water	12
Ari conditioner	2.0	Others	13
Household Appliances	0.2	Total	79
Others	1.2		
Total	7.1		

The results have been modified according to actual situation of the island regions. Table 1 shows the estimated daily demand of water and power per capita. The daily demand of energy is about 7.1 kW·h per capita. Table 1 shows the estimated daily demand of water per capita in the island and the type of demand. The daily demand of water is about 79 liters per capita.

It will use 10.0-20.0 kW·h electricity to produce one cubic meter of desalinated water. Suppose all water resources are provided by sea-water desalination, one person requires 1.8 kW·h electricity for water-supply. The daily demand of energy is about 9.0 kWh per capita, together with other energy needs 7.1 kWh.

Figure 3 shows the comparison of output process of renewable energy and daily load process in a typical island. It can be seen from the figure that, the output process of renewable energy generation is fitting well with the daily load process, which is conducive for renewable energy supply.

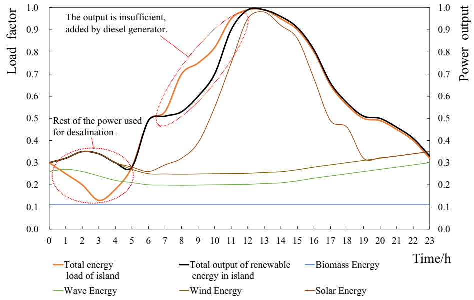

Figure. 3. Output process of renewable energy and daily load process

4. Maldives: construction of renewable energy-driven island system

4.1. Energy and water resources situation in Maldives

Maldivian traditional energy source is based on the outside supply, and the most common form is the small diesel power plant, and there is no uniform grid, which results in vulnerability of the power supply. Currently, the electricity price is very high in Maldives, and diesel power generation brings large emission of greenhouse gases and pollutants, which has adversely impacted local tourism development.

There are no inland rivers in the Maldives archipelago, only a few wetlands and freshwater lakes. Since freshwater and seawater are connected in island, freshwater resources are extremely fragile in Maldives. There are almost no surface water resources, and most of the water resources are stored underground.

4.2. Maldivian renewable energy assessment

Maldivian renewable energy sources include solar, wind, hydro, wave, tidal and biomass energy. However, due to the unique geological structure and topography, hydropower development is less likely. The potential and technology of ocean, wave and tidal energy needs further study.

Solar energy is the most abundant clean energy in Maldives, estimated Maldives solar energy reserve is about 5.7×10^{11} kWh / y. Maldives is also rich in wind resources, with a wind speed at 50m height in N4.7° regions of 6.4~6.7m/s, classified by IEC classification standards as Ⅲ class wind farm, estimated Maldives wind reserve is about 3.8×10^{11} kWh/y. The biomass power, which can both save waste disposal costs and provide energy, and estimated Maldives biomass energy reserve is about 4.6×10^{8} kWh/y.

Maldives has a population of 390,000, the number of visitors are 2~3 times of native, and the average visiting time is five days. Assuming the demand of energy per capita to be 9.0kWh/d (from 3.1), the annual need of Maldives is approximately 1.3×10^{9} kWh. The sum of Maldives solar, wind and biomass energy is about 9.51×10^{11}kWh, which is much larger than the energy demand. So Maldives renewable energy reserves would be able to meet its demand.

4.3. Maldivian Renewable energy-driven systems

Maldives is far away from the mainland, without large-scale conventional energy or freshwater resource. To maintain current scale and speed of socio-economic development, a more reliable energy and fresh water-supply scheme must be found. Despite the energy and water resources deficiencies, Maldives has its unique advantages on inexhaustible renewable energy and seawater resources. Through combining them into a combined, efficient energy-water joint solution mode, living and developing conditions in Maldives can be greatly improved.

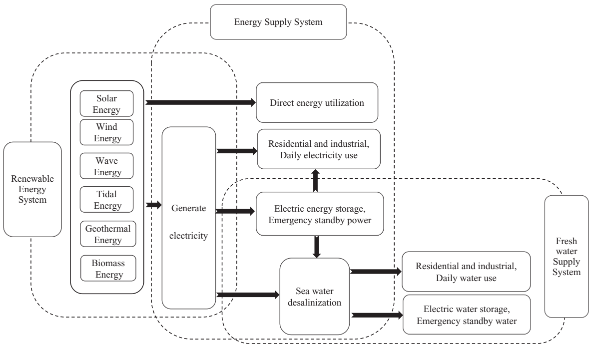

Figure .4. Renewable energy-driven systems in Maldives island

Figure 4 shows the conceptual framework for renewable energy-driven Maldivian system, which consists of renewable energy system, energy supply system and freshwater-supply system. The energy and fresh water-supply system is driven by renewable energy systems. The general idea is: a small part of the obtained renewable energy is directly used (i.e. solar power for domestic lighting and cooking), and the main part generates electricity to supply other various needs (i.e. electricity utilization and desalination systems).

Since the generation process of renewable energy power and the actual power load process may not match precisely, an approach to self-adjusting technology for variable load should be taken. Electricity generated by renewable energy should be supplied to users instantly. When generated output is greater than the electrical load, distributed electric energy storage should be adopted for supply in emergency or when generated output is insufficient; on the other hand, considering the technical difficulties of large energy saving device, the solution is "saving water instead of electricity" .

4.4. Critical issues of Maldivian renewable Energy-driven system

Complementary power generation technology. A single energy is difficult to provide stable power, the use of multiple marine renewable energy power generation technology can solve this problem;

Large-scale power energy storage technology. The power system of island is more vulnerable, large-scale power energy storage is really necessary;

Flexible start and stop technology of desalination system. In order to adapt to uneven output of renewable energy, desalination plant is often required to be closed and started;

Financing and investment management. Exploring for the energy and water management of the coupled network of renewable energy and energy-driven non-freshwater-import island system is needed.

5. Conclusion

This paper has proposed a renewable energy-driven water-supply system with “Zero Input of Energy & Water”. The system can be achieved through the promotion of renewable energy development and utilization, strengthening highly coupled energy systems and water systems. The system can also realize "carbon neutral" and "zero pollution". Through Maldives’s energy and water demand analysis and local renewable energy assessment, it can be noted that it is feasible to establish a renewable energy-driven water-supply system.

6. Copyright

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Prof. Jiahong Liu has published more than 120 scientific papers, more than 50 of them was indexed by SCI and EI. And he has won the provincial and ministerial awards for more than 8 times, including GFHS Award of Green Technology, the National First Prize for scientific and technological advancement.