Combination of renewable energies and a simple desalinator used in land aqua-farms in Taiwan

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Abstract

Renewable energy has its own application potential and limitation, according to the in-situ natural force. If appropriate renewable energy sorts are selected and operated complementarily, the overall performance and potential supply time are anticipated to be higher than those operated individually. For example, electricity generation by solar and wind power are limited by the local sunshine and wind quality. In coastal areas, these could be well arranged and operated complementarily to raise the electricity supply quality and obtain the maximum natural resource. This study establishes a complementary operation system, consisting of 0.5KW PV, 1.4KW small-scale wind power, batteries, AC/DC DC/AC inverters, etc. A 1KW simple desalinator was selected as the power consumer and powered by this complementary system. Nodal electric data and system performance were measured. HOMER, developed at the National Renewable Energy Laboratory, USA, was used to illustrate and evaluate the technical and economic aspects in planning the desalination in a conventional land aqua-farm in Taiwan.

Keywords: renewable energy, solar, wind, aquafarm, HOMER.

1 Introduction

If a renewable energy is exploited individually, its inherent power supply defects might limit the development of its application. In contrast, if suitable forms of renewable energies are selected and used complementarily, then the power
supply of the entire system will increase. For instance, electricity generated by solar and wind power is restricted by wind speed and the amount of sunshine. If industries along the coast can make use of the complementary advantages of wind and sunlight, then the electricity supply will be maximized natural force [1–5].

Land aquaculture is prevalent along the coast in Taiwan, where the high winds and sunlight are complementary. Supported by the Tainan City Government and equipment manufacturers, this study selected a suitably sized land aquafarm of an appropriate type, and established a hybrid system that consists of 1.4KW small-scale wind power and 0.75KW PV. At the initial stage, annual meteorological information collected from Central Weather Bureau of Taiwan and a self-deployed weather station were used to estimate the electricity supply of this hybrid system for the purpose of system design. Fig.1 presents the system illustration. The electrical equipment used in land aquafarms includes the desalinator, gas irrigators, night lighting, feedwater and drainage pumps, and automatic-feeding machines. This study designed a simplified desalinator as an experimental example, which performed a simplified distillation process, and was small, efficient, cheap, user friendly and easy to build, as shown in Fig. 2. The water distilled by this desalinator was cooled naturally and poured into the land aquafarm, whenever necessarily. The effectiveness of the use of this hybrid system with the simplified desalinator was assessed using the simulation software HOMER.

2 Testing the operation of the system

After the hybrid power system had been established, a FLUKE power quality analyzer 43B and a FLUKE teue-rms multimeter 189 were used to measure electrical data, including voltage/current waves, the amount of electricity generated, the quality of the power and the status of the batteries. The actual amount of electricity generated was then compared with the estimated output. The results were divided into three parts.
2.1 Output of fresh water

The simplified desalinator was set to operate during the day, to suit the fishermen’s working pattern, as demonstrated in Fig.3. After a 90 minute warm-up period, fresh water began to flow. The temperature of the out-flowing water was about 35℃. The output of fresh water increased slightly with the temperature at noon and in the afternoon. On average, the output of fresh water per hour was 0.37 liter.

![Figure 3: Fresh water output of the simplified desalinator.](image)

2.2 Performance of the AC/DC inverter

The input port of the AC/DC inverter was connected to the wind power generator, and its output port was connected to a storage battery controller. Therefore, the outdoor wind quality affected the power status of the input port and the electricity conversion efficiency of the inverter. Fig.4 reveals that when the average wind speed on a day was lower, the efficiency of the AC/DC inverter...
increased. However, the average wind speed on December 19 was high, and the wind velocity changed drastically. The input electric power fluctuated more, so the performance of the AC/DC inverter declined to 88%.

![Graph showing measured performance of the AC/DC inverter](image)

Figure 4: Measured performance of the AC/DC inverter in this study.

### 2.3 Performance of the DC/AC inverter

The input port of the DC/AC inverter was connected to the battery controller, and its output port was connected to the constant load desalinator. The performance of this inverter will not be directly influenced by the quality of the wind or sun. The conversion performance is 92.5–95.6%.

### 3 Applying HOMER to assess hybrid system applications

HOMER (Hybrid Optimization Model for Electric Renewables), developed at the National Renewable Energy Laboratory, USA, could be used to illustrate and evaluate the technical and economic aspects of the planning of a wide range of applications (gas irrigator, desalination, lighting, automatic feeder and heating) in a conventional Taiwanese land aquafarm, with a view to creating the best system at the lowest cost. The limitations of HOMER are such that the load cannot be set in a way that matches real situation. Accordingly, the author could not use HOMER to evaluate the whole case, but adopted Homer’s electricity generation results (Table 1) as a basis to perform a manual evaluation.
Table 1: Simulated energy output of the hybrid system by HOMER.

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<tbody>
<tr>
<td>Hourly power output (kw)</td>
<td>0.27</td>
<td>0.25</td>
<td>0.22</td>
<td>0.23</td>
<td>0.13</td>
<td>0.15</td>
<td>0.19</td>
<td>0.14</td>
<td>0.17</td>
<td>0.25</td>
<td>0.24</td>
<td>0.27</td>
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<tr>
<td>Daily energy output (kw-hr)</td>
<td>6.41</td>
<td>5.95</td>
<td>5.38</td>
<td>5.50</td>
<td>3.12</td>
<td>3.60</td>
<td>4.56</td>
<td>3.24</td>
<td>4.08</td>
<td>6.00</td>
<td>5.81</td>
<td>6.36</td>
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The sunlight rapidly evaporated the water in the land aquafarms during the summer evaporated, increasing the salinity. Hence, fishermen often purchase more fresh water to add to the aquafarms to reduce salinity. This study adjusted the operation time of the desalinator to respond to the various electricity outputs estimated by HOMER. If the gross generation of electricity was sufficient in consecutive days, the desalinator could be operated for days. When the generation of electricity was low (as on rainy days), the desalinator was operated occasionally, waiting for the battery to be able to operate at full capacity. In summary, the period of operation was adjusted according to the generation of electricity. The electricity generation in Table 1 was used to predict the output of fresh water, and the results were presented in Table 2.

Table 2: Operation of the simplified desalinator and fresh water production.

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<tr>
<td>Duration of charging battery (day)</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Daily operation time (hr)</td>
<td>8.5</td>
<td>8</td>
<td>8.5</td>
<td>7.5</td>
<td>8</td>
<td>7</td>
<td>8.5</td>
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<tr>
<td>Daily power consumption (kw)</td>
<td>9.775</td>
<td>9.2</td>
<td>9.775</td>
<td>8.625</td>
<td>9.2</td>
<td>8.05</td>
<td>9.775</td>
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<tr>
<td>Monthly fresh water production (L)</td>
<td>41.55</td>
<td>25.7</td>
<td>27.7</td>
<td>35.55</td>
<td>25.7</td>
<td>32.55</td>
<td>41.55</td>
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<tr>
<td>Yearly fresh water production (L)</td>
<td></td>
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<td>230.3</td>
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</table>

4 Conclusion

This study selected a suitably sized land aquafarm of an appropriate type, and established a hybrid system with 1.4KW small-scale wind power and a 0.75KW PV outputs. Experiments and simulations were carried out to evaluate their complementary operation and diverse applications in a conventional land aquafarm in Taiwan. A 1KW simple desalinator was designed and powered by this hybrid system. A 90minute warm-up period was required to produce fresh water. The average hourly output of fresh water per was 0.37 L and its temperature was about 35℃. The outdoor wind quality affects the electricity conversion performance of the AC/DC inverter, which had an average efficiency of 88%. Neither the quality of the wind nor sun the directly influenced the...
performance of the DC/AC inverter, which exhibited a conversion performance of 92.5–95.6%. The HOMER software was used to illustrate and evaluate the technical and economic aspects of the desalination driven by the hybrid system. This text provides detailed information.

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Reference