Design of Wind Turbine types for Hybrid Power System in Bawean Island

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ABSTRACT

Today the electricity supply to Bawean region is at least 8,000 families not yet gotten by electricity. The primary load needed is 2.8 MWh /day with peak load of 454 kW. A software tool, the Hybrid Optimization Model for Electric Renewables (HOMER) is used for the analysis. In this project, the HOMER analysis focused on the type of wind turbine that will be used and then the results were compared based on the total NPC, COE, excess electricity generated and renewable fraction. The Wind turbine types selected are BWC Excel R (DC), Synergy S3000 (DC), Synergy S20000 (DC), Synergy S5000DD (DC), Jacobs 29-20 (AC), Fuhrlander 250 (AC) and Fuhlander 30 (AC).

***Keywords** : turbine, hybrid, HOMER, Bawean*

1. Introduction

Bawean is located latitudes 5º 46’ and longitudes 112º 40’ East. It is an island of Indonesia located approximately 150 km north of Surabaya in the Java Sea, off the coast of Java. It is administered by Gresik Regency of East Java province. It is approximately 15 km in diameter and is circumnavigated by a single narrow road. Bawean is dominated by an extinct volcano at its center that rises to 655 m above sea level.

Today the electricity supply to Bawean region is at least 8,000 families not yet gotten by electricity. The primary load needed is 2.8 MWh /day with peak load of 454 kW. The aim of design of wind turbine for hybrid power system in Bawean Island is to optimize the produced of electricity from wind in economic and environment aspect. The Wind turbine types selected are BWC Excel R (DC), Synergy S3000 (DC), Synergy S20000 (DC), Synergy S5000DD (DC), Jacobs 29-20 (AC), Fuhrlander 250 (AC) and Fuhlander 30 (AC).

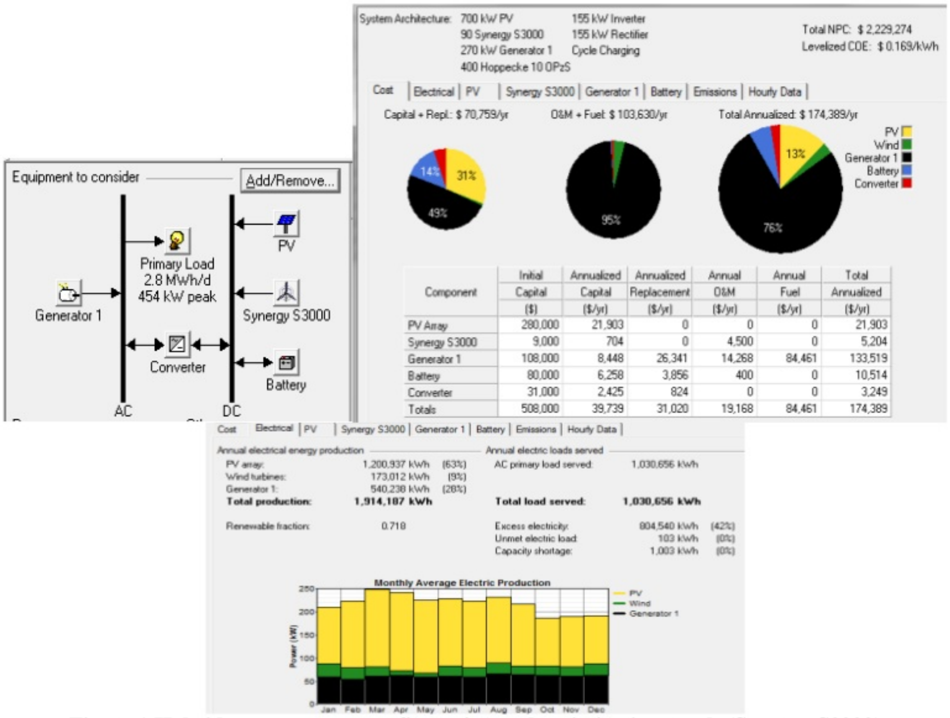
2. Hybrid Power System

There is a huge potential for utilizing renewable energy sources, for example solar energy, wind energy, or micro hydropower, to provide a quality power supply to remote areas. The abundant energy available in nature can be harnessed and converted to electricity in a sustainable way to supply the necessary power to elevate the living standards of the people without access to the electricity grid[1].

The advantages of using renewable energy sources for generating power in remote islands are obvious such as the cost of transported fuel are often prohibitive fossil fuel and that there is increasing concern on the issues of climate change and global warming. The disadvantage of standalone power systems using renewable energy is that the availability of renewable energy sources has daily and seasonal patterns which results in difficulties in regulating the output power to cope with the load demand. Combining the renewable energy generation with conventional diesel power generation will enable the power generated from renewable energy sources to be more reliable and affordable. This kind of electric power generation system, which consists of renewable energy and fossil fuel generators together with an energy storage system and power conditioning system, is known as a hybrid power system[1].

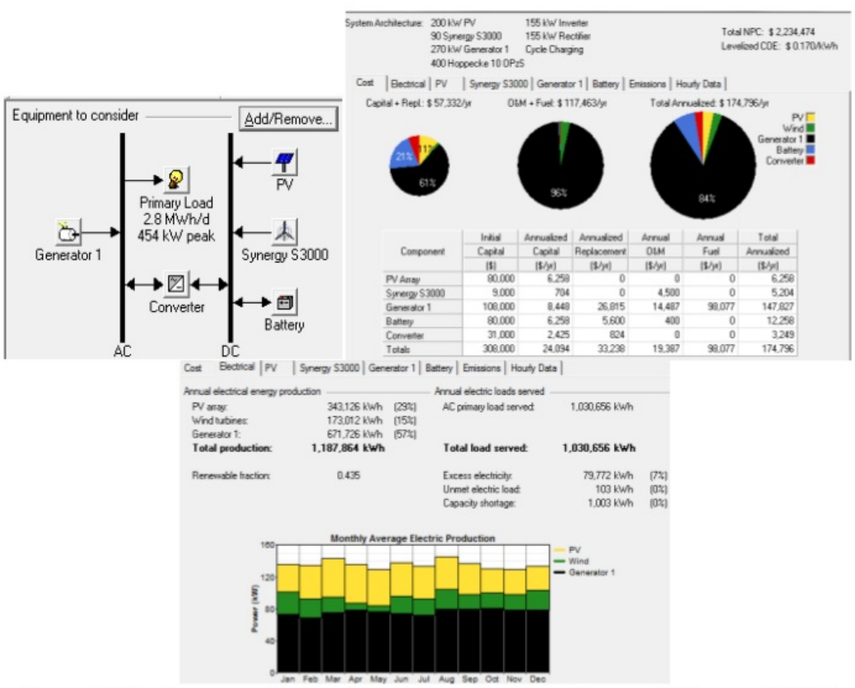
A hybrid power system has an ability to provide 24-hour grid quality electricity to the load. This system offers a better efficiency, flexibility of planning and environmental benefits compared to the diesel generator stand-alone system. The operational and maintenance costs of the diesel generator can be decreased as a consequence of improving the efficiency of operation and reducing the operational time which also means less fuel usage. The system also gives the opportunity for expanding its capacity in order to cope with the increasing demand in the future. This can be done by increasing either the rated power of diesel generator, renewable generator or both of them[2].

3. System Components



Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
PV Array	280,000	21,903	0	0	0	21,903
Synergy S3000	9,000	704	0	4,500	0	5,204
Generator 1	108,000	8,448	26,341	14,268	84,461	133,519
Battery	80,000	6,258	3,856	400	0	10,514
Converter	31,000	2,425	824	0	0	3,249
Totals	508,000	39,739	31,020	19,168	84,461	174,389

Figure 1 Hybrid power system configuration and optimization result (Synergy S3000)



Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
PV Array	80,000	6,258	0	0	0	6,258
Synergy S3000	9,000	704	0	4,500	0	5,204
Generator 1	108,000	8,448	26,815	14,487	98,077	147,827
Battery	80,000	6,258	5,600	400	0	12,258
Converter	31,000	2,425	824	0	0	3,249
Totals	308,000	24,094	33,238	19,387	98,077	174,796

Figure 2 Hybrid power system configuration and optimization result (Synergy S3000)

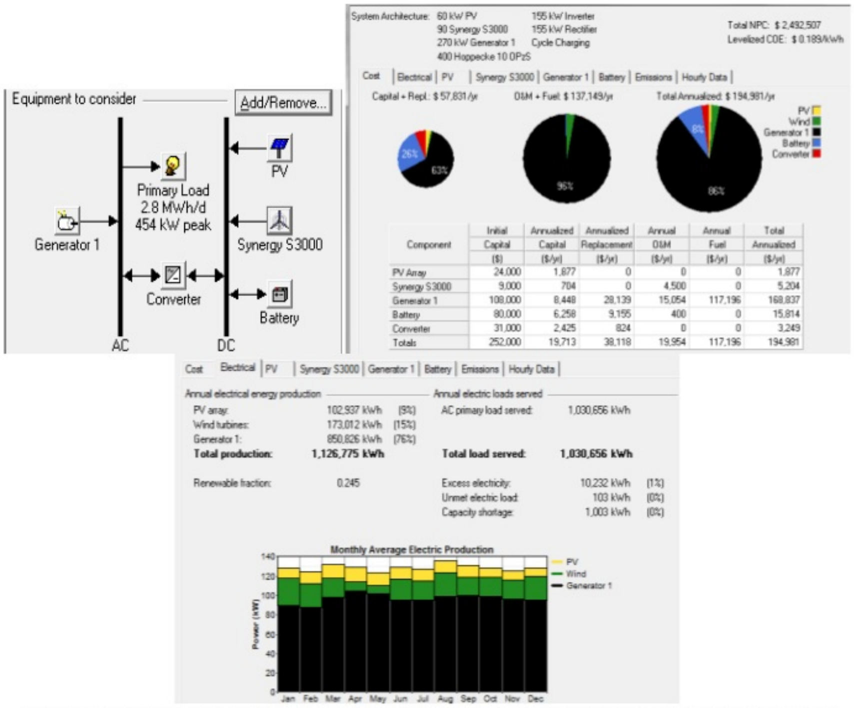


Figure 3 Hybrid power system configuration and optimization result (Synergy S3000)

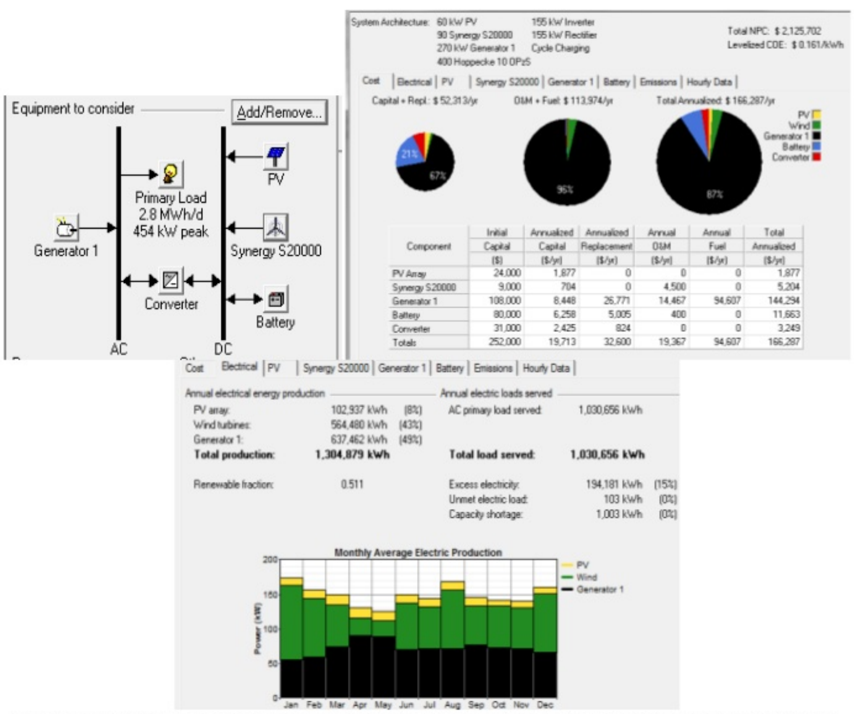


Figure 4 Hybrid power system configuration and optimization result (Synergy S20000)

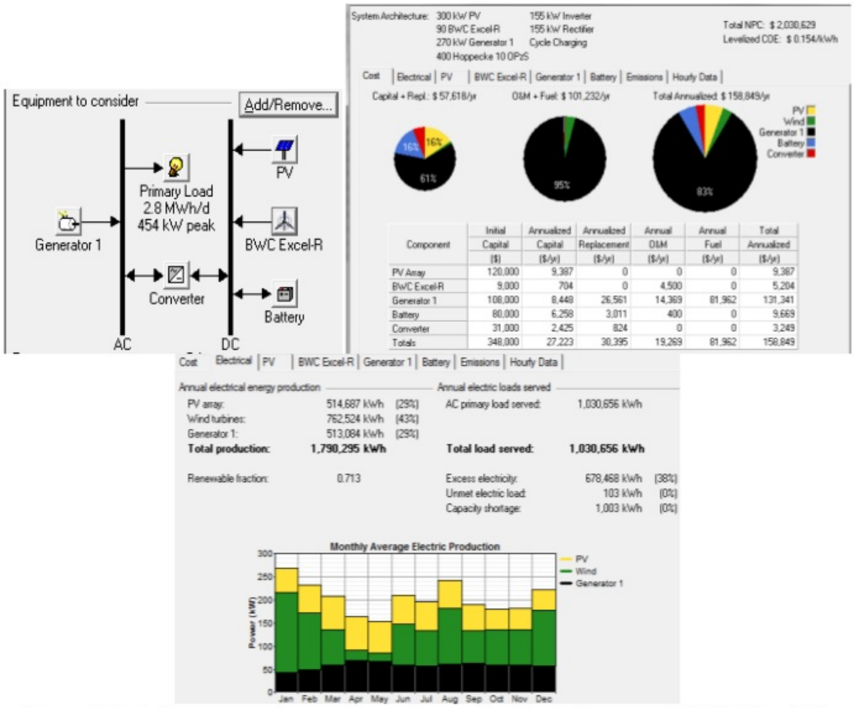


Figure 5 Hybrid power system configuration and optimization result (BWC Excel R)

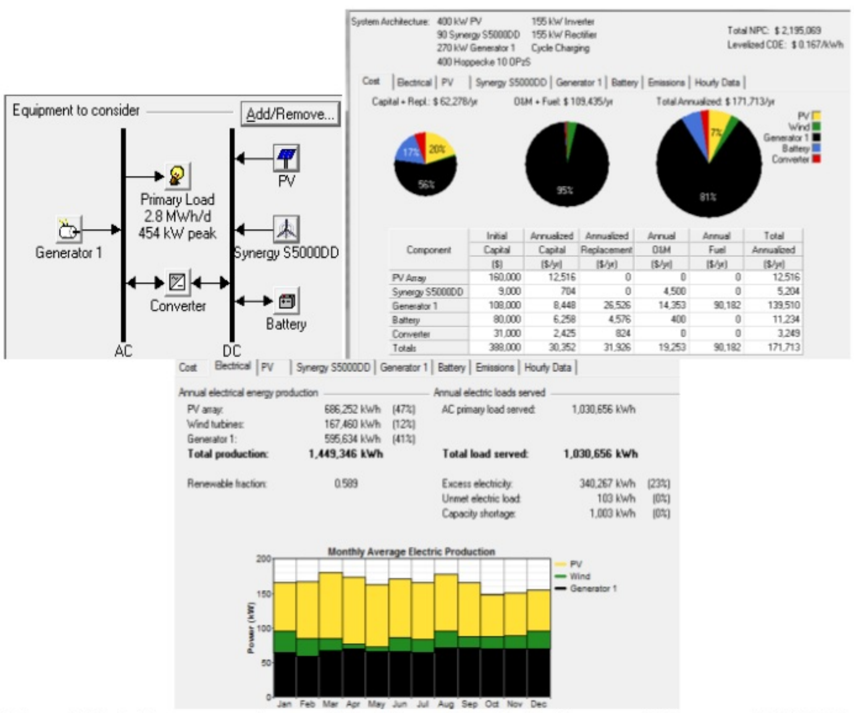


Figure 6 Hybrid power system configuration and optimization result (Synergy S5000DD)

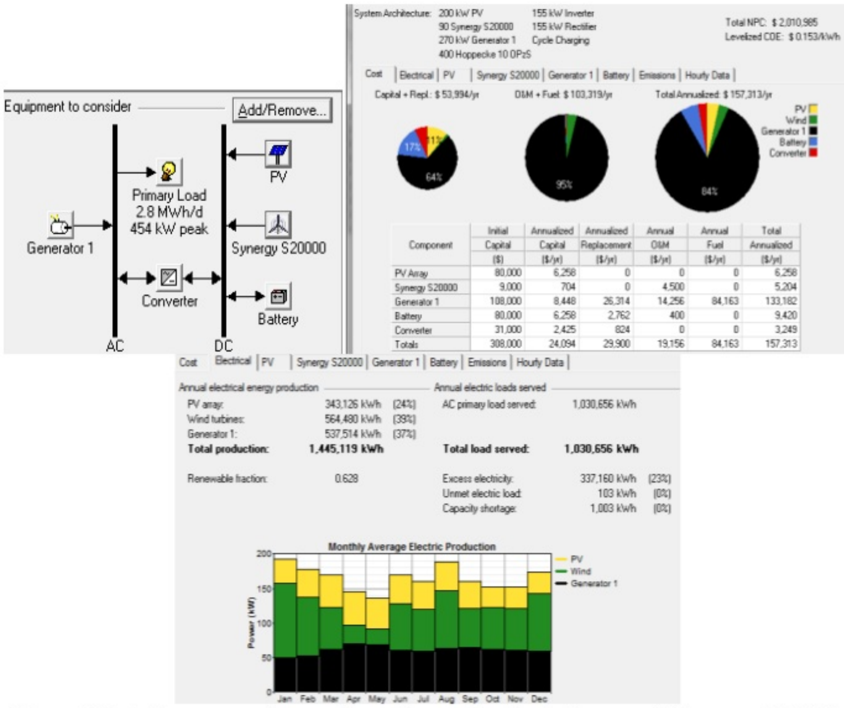


Figure 7 Hybrid power system configuration and optimization result (Synergy S20000)

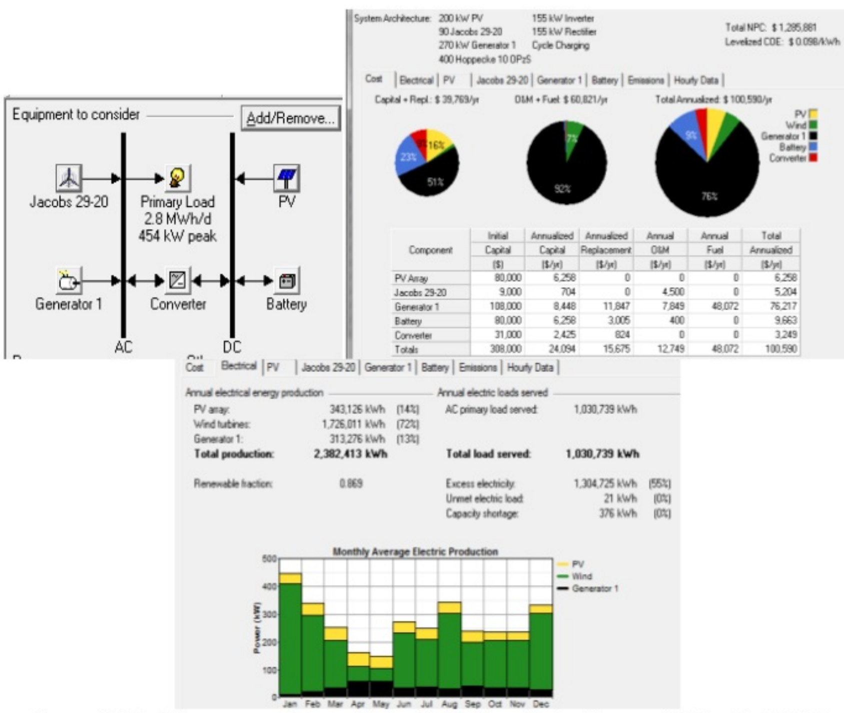


Figure 8 Hybrid power system configuration and optimization result (Jacobs 29-20)

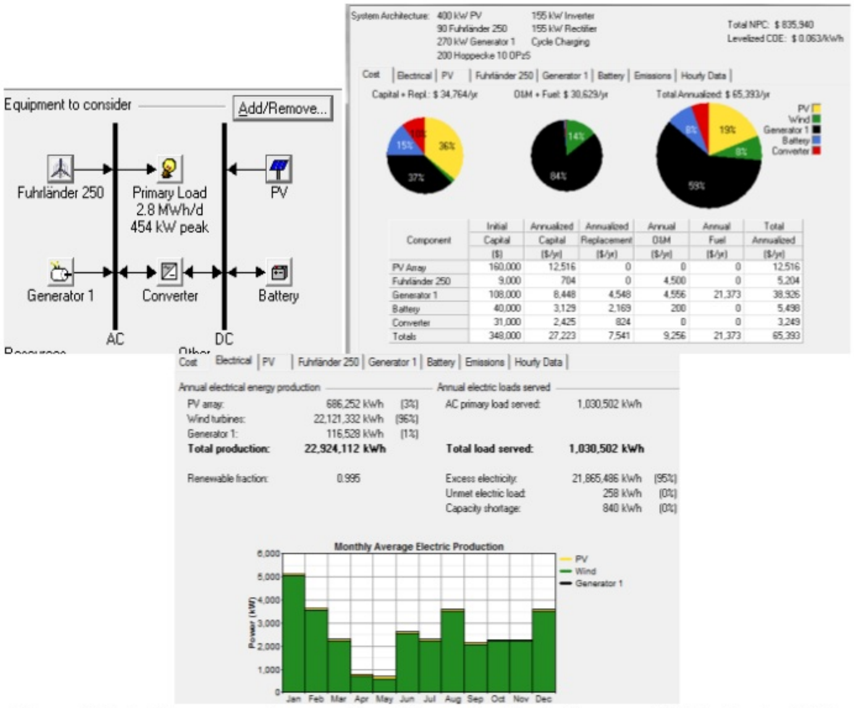


Figure 9 Hybrid power system configuration and optimization result (Fuhrlander 250)

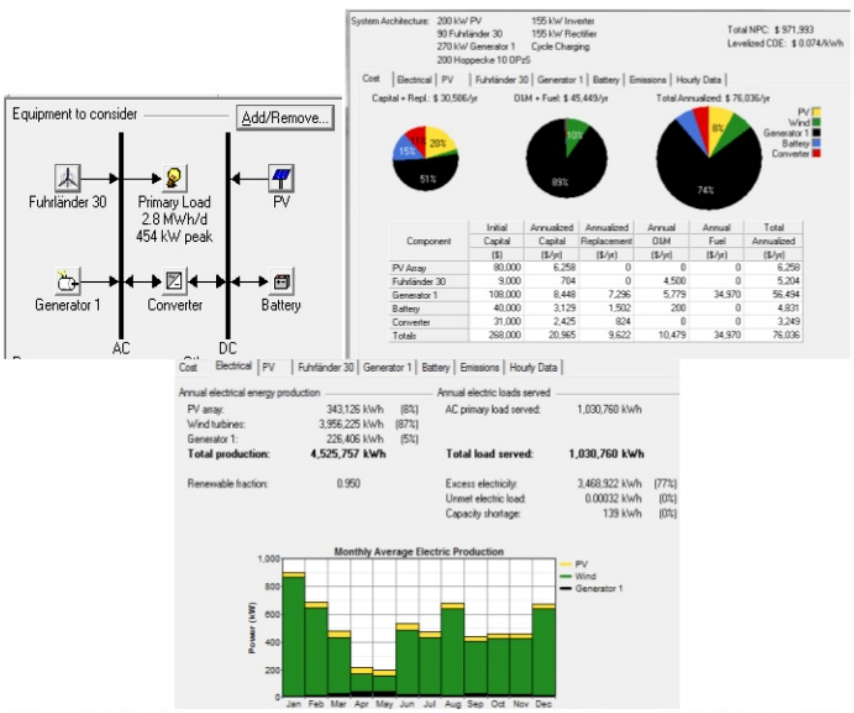


Figure 10 Hybrid power system configuration and optimization result (Fuhrlander 30)

Figure 1 to Figure 10 showed system components in every types of wind turbine in HOMER diagram, cost summary for an utilization of renewable resources and contribution of the power units for an utilization of renewables.

4. Simulation Result

Table 1 Comparation of simulation results of wind turbine system components

	Wind Turbine (Quantity= 90)									
	BWC Excel R	Synergy S3000			Synergy S20000		Synergy S5000DD	Jacobs 29-20	Fuhrlander 250	Fuhlander 30
	Fig. 5	Fig. 3	Fig. 2	Fig. 1	Fig. 4	Fig. 7	Fig.6	Fig. 8	Fig.9	Fig.10
PV Array (kW)	100	50	100	500	50	100	100	100	100	100
	200	**60**	**200**	600	**60**	**200**	200	**200**	200	**200**
	300			**700**		300	300	300	300	300
	400			800		400	**400**	400	**400**	400
	500			900		500	500	500	500	500
	1000			1000		1000	1000	1000	1000	1000
Gen1 (kW)	270	270	270	270	270	270	270	270	270	270
Batteries (Quantity)	100	100	100	100	100	100	100	100	100	100
	200	200	200	200	200	200	200	200	**200**	**200**
	300	300	300	300	300	300	300	300		
	400	**400**	**400**	**400**	**400**	**400**	**400**	**400**		
	500	500	500	500	500	500	500	500		
Converter	155	155	155	155	155	155	155	155	155	155
Total NPC ($)	2,030,629	2,492,507	2,234,474	2,229,274	2,125,702	2,010,985	2,195,069	1,285,881	835,940	971,993
COE ($/kWh)	0.154	0.189	0.170	0.169	0.161	0.153	0.167	0.098	0.063	0.074
Total production (kWh)	1,790,295	1,126,775	1,187,864	1,914,187	1,304,879	1,445,119	1,449,346	2,382,413	22,924,112	4,525,757
Excess electricity	38 %	1 %	7 %	42 %	15 %	23 %	23 %	55 %	95 %	77 %
Renewable fraction	0.71	0.24	0.43	0.72	0.51	0.63	0.59	0.87	0.99	0.95

: DC

: AC

Based on the characteristic of system components are indicated by color for every type of wind turbine in Table 1 it can be seen:

1. Based on the result given in Table 1, the total NPC for wind turbine AC is smaller than DC that showed by value of COE. That means the wind turbine AC more economical than DC.
   - ➢ Wind tturbine DC (BWC Excel R, Synergy S3000, Synergy S20000 and Synergy S5000DD)
     - Economic reason: wind turbine type Synergy S20000 more economical than BWC Excel R, Synergy S3000 and Synergy S5000DD with total NPC is $2,010,985 and the COE is 0.153 $/kW h.
     - Excess electricity reason: wind turbine type Synergy S3000 is better than BWC Excel R, Synergy S20000 and Synergy S5000DD with 42 % excess electricity.
     - Environment reason: wind turbine type Synergy S3000 more environment friendly than BWC Excel R, Synergy S20000 and Synergy S5000DD with renewable fraction 0.72.
   - ➢ Grey color (BWC Excel R, Synergy S20000 and Synergy S5000DD)
     - Economic reason: wind turbine type Synergy S20000 more economical than BWC Excel R and Synergy S5000DD with total NPC is $2,010,985 and the COE is 0.153 $/kW h.
     - Excess electricity reason: wind turbine type BWC Excel R is better than Synergy S20000 and Synergy S5000DD with 38 % excess electricity.
     - Environment reason: wind turbine type BWC Excel R more environment friendly than Synergy S20000 and Synergy S5000DD with renewable fraction 0.71.
   - ➢ Yellow color (Synergy S3000 and Synergy S20000)
     - Economic reason: wind turbine type Synergy S20000 more economical than Synergy S3000 with total NPC is $2,125,702 and the COE is 0.161 $/kW h.

   The total excess electricity for wind turbine AC is bigger than DC that showed performance of wind turbine AC is better than DC. The value of renewable fraction on wind turbine AC is higher than DC, it means wind turbine AC more environment friendly than DC.
2. For the wind turbine DC:
     - Excess electricity reason: wind turbine type Synergy S20000 is better than Synergy S3000 with 15 % excess electricity.
     - Environment reason: wind turbine type Synergy S20000 more environment friendly than Synergy S3000 with renewable fraction 0.51.
   - ➢ Synergy S3000 (yellow, pink and green)
     - Economic reason: wind turbine type Synergy S3000 with the system components such as in green color more economical than the others (yellow and pink) with total NPC is $2,229,274 and the COE is 0.169 $/kW h.
     - Excess electricity reason: wind turbine type Synergy S3000 with the system components such as in green color is better than the others (yellow and pink) with 42 % excess electricity.
     - Environment reason: wind turbine type Synergy S3000 with the system components such as in green color more environment friendly than the others (yellow and pink) with renewable fraction 0.72.
   - ➢ Synergy S20000 (yellow and grey)
     - Economic reason: wind turbine type Synergy S20000 with the system components such as in grey color more economical than yellow with total NPC is $2,010,985 and the COE is 0.153 $/kW h.
     - Excess electricity reason: wind turbine type Synergy S20000 with the system components such as in grey color is better than yellow with 23 % excess electricity.
     - Environment reason: wind turbine type Synergy S20000 with the system components such as in grey color more environment friendly than yellow with renewable fraction 0.63.

3. For the wind turbine AC:
    - Wind turbine AC (Jacobs 29-20, Fuhrlander 250 and Fuhrlander 30)
        - Economic reason: wind turbine type Fuhrlander 250 more economical than Jacobs 29-20 and Fuhrlander 30 with total NPC is $835,940 and the COE is 0.063 $/kW h.
        - Excess electricity reason: wind turbine type Fuhrlander 250 is better than Jacobs 29-20 and Fuhrlander 30 with 95 % excess electricity.
        - Environment reason: wind turbine type Fuhrlander 250 more environment friendly than Fuhrlander 30 with renewable fraction 0.99.
    - Blue color (Fuhrlander 250 and Fuhrlander 30)
        - Economic reason: wind turbine type Fuhrlander 250 more economical than Fuhrlander 30 with total NPC is $835,940 and the COE is 0.063 $/kW h.
        - Excess electricity reason: wind turbine type Fuhrlander 250 is better than Fuhrlander 30 with 95 % excess electricity.
        - Environment reason: wind turbine type Fuhrlander 250 more environment friendly than Fuhrlander 30 with renewable fraction 0.99.

5. Conclusion

The design of wind turbine types for hybrid power system in Bawean Island is presented here. Generally in the same quantity of wind turbine (90), design wind turbine AC for hybrid power systems is better than DC. The best performance in wind turbine AC is Fuhrlander 250 with the lowest of total NPC and COE ($835,940 and 0.063 $/kW h), and the highest of excess electricity (95 %) and renewable fraction approaching 1 (0.99) that mean if Fuhrlander 250 generated the lowest pollutant than other wind turbine.

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