Design optimization of hybrid biomass and wind turbine for minapolitan cluster in Domas, Serang, Banten, Indonesia

Erwin Erwin[1,2], **Tresna P Soemardi**[1], **Adi Surjosatyo**[1], **Julianto Nugroho**[1], **Kurnia Nugraha**[2], **Slamet Wiyono**[2]

[1] Mechanical Engineering, University of Indonesia, Depok, Indonesia.
[2] Mechanical Engineering, Sultan Ageng Tirtayasa University, Cilegon, Indonesia.

E-mail: erwin@untirta.ac.id

Abstract. This research aims is to design a renewable energy power plant based on the renewable energy potential in Domas village. Domas is a coastline that has a wind speed is has the potential to develop a wind power plant with enough capacity that can be utilized economically; in addition Domas is also a centre of rice and rice husks producer. Economic activity as a farmers and milkfish breeders and this area is set to be minapolitan area of Serang district. The problem is many of the ponds is placed far from electricity, so it requires another alternative as a source of electrical. Aquaculture requires aeration and lighting to increase fish and shrimp production, to keep the oxygen content dissolved in water. Lighting are required starting at 6 pm to 6 am, and the aerators based on the shrimp and fish life cycle are required to be switched on from 5 pm to 6 am. Wind data is obtained from Homer, meteonorm and NOAA databases, which is then processed in Homer for optimization. Potential data of husk is obtained from ministry of energy and mineral resources of the republic of Indonesia (EMR) database for Serang regency in 2016. For 1 hectare of land with 1.5 tons of fish, total electricity needed 2.4 kWh per day for lighting and 13 kWh per-day for aerator, with peak of 0.385 kW and 1.9 kW. By using the Aeolos 500 wind turbine as non-dispatchable resource and biomass generator as a dispatchable resource, a simulation is performed to get the system that produces the lowest LCOE (Levelized Cost of Electricity) and highest renewable energy (REN) factor for wind turbine. The recommended system is 2 kW Biomass Generator, 10 kW Inverter, 10 kW Rectifier, 24 Battery Trojan L18P 360 Ah capacity with 8 units of Aeolos 500 array. With economic LCOE $0.445 / kWh, and 82.2 % REN factor for wind turbine.

1. Introduction

Sources of renewable energy have become an alternative to the supply of electric energy for remote areas. Domas village located in the Serang district within no more than 20 km from Serang city center. The village is near on Java sea beach . Domas village is a Minapolitan Village with milky fish and shrimp as a main aquaculture. This study aims to design and provide a hybrid system of renewable energy plant to powering the fish and shrimp pond, alternative energy sources that will be used is biomass and wind using local potential characteristic.

Recently, research on the fluctuations in energy generated by wind turbines is highly dependent on the intensity of wind turbulence [1] research integration of different renewable energy sources has been done to improve the sustainability of the supply of electric energy [2-3]. The problem that arises is how to manage this energy source [4], optimization [6-7] and determine the size of each generator [8] for efficient and optimum economical and technical value. Research on hybrid biogass and wind turbine simulations based on real data shows more reliable energy production to produce stabilized at 40 MW in Spain [9]. HOMER software that is issued by NREL was become one alternative in the initial study to conduct a feasibility study [5] the integration of renewable energy sources. Sultan wind turbine is design to meet the specific wind potential behaviour in Serang district [11] and in the future research will used as a main wind turbine in this system. In term of gasification, using sand to prevent agglomeration in gasification with coconut shell and wood pellets [12]. using rice husk ash mass effect to sustain pyrolysis process [13]. The development of job creation formation model in renewable energy sector is offered because of the magnitude of renewable energy potential in Indonesia [19]. CFDs are used to analyse and optimize the integrated wind turbine on buildings [20]. This Research focus on developing the optimized of dispatch-able wind power and non-dispatch-able biomass hybrid plant system, that can electrified the aerator and others need in milkfish pond.

2. Method

Hybrid system is more preferred over a single system due to a more stable performance along a year [16]. This research firstly did an investigating of potential renewable energy by collecting data from secondary data such as from Meteonorm database, meteorology station from NOAA website, Homer database for wind speed and ESDM database for biomass potential. This data will be used as an input in optimization designing renewable energy plant using Homer beta 2 Software.

2.1 Wind potential investigation

Annual average wind speed in Domas according to meteonorm 3.18 m/s, also lower than Garissa Kenya [17]. In this research wind data also collected from homer database. Wind velocity data from local meteorological stations are taken in the NOAA database, at an average speed of 3 m/s, in addition to wind speed data also taken from the meteonorm database and the homer database. The village of Domas is located at -5.990 N 106.254 E, in the Meteonorm database has the potential for sunlight and wind throughout the year as shown below.

Table 1. Data of wind potential in Domas village average monthly

Month	Meteonorm	NOAA
January	3.6	2.225806
Febuary	2.6	2.243333
March	3.1	2.080645
April	2.6	1.656667
Mei	2.6	1.877419
June	3.1	1.7
July	3.1	1.682759
August	3.6	1.432258
September	3.6	1.446667
October	3.1	1.325806
November	3.6	1.34
December	3.6	1.43871

2.2. Biomass potential investigation

From ministry of energy and mineral resources, in Serang city, rice husk is a biggest potential of biomass. Domas village with about 50 families, and every family, average have 1 hectare of paddy field, and produce rice 6.15 tons rice per hectare for four times a year, and produce about rice husk 28 tons per year, means every day about 70kg of rice husk for every family. So for biomass have potentially 350 kg daily. In this case biomass will be process to produce biofuel using gasification with max capacity 30 HP, with feeding speed, 30 kg rice husk per hour.

The biomass potential obtained from ministry of energy and mineral resources of the republic of Indonesia (*EMR*) for 2017, from the table indicates considerable potential and is technically entirely unused, potentially equivalent to a medium-sized generator.

Table 2. Biomass potential data obtained from EMR report for Serang Banten area

District	Sources	Industrial Type	Potential (MWe)			Used	
			Global	Technical	Optimized	On grid	Off grid
Serang	Farming	Husk Farming	67.86	4.95	0	0	0
	Municipal Garbage	Municipal Garbage Potential	12.2	0	0	0	0

2.3. Load calculation

To obtain data real electrical energy requirements for a pond then needs to be calculated on the equipment needed and electrical needs, such as aeration tools and magnitude, lighting and other logistic needs.

A pond needs lights for lighting and aerators to keep oxygen levels in the water. Lighting and home appliance are required starting at 6 pm to 6 am, and aerators based on the shrimp and fish life cycle are required to be switched on from 5 pm to 6 am.

Ordinary farmers have up to 2 hectares of ponds, intensive ponds have a distribution capacity of up to 5 tails per m2, and it takes 3 waterwheels per plot (0.5 Ha) the load calculation will use a 2 hectare base with 4 pool plots. Overall average electricity required 2.4 KWh per day for lighting and 13 KWh per day for aerator, with peak of 385 watt and 1.9 Kw respectively.

This system is designed for the whole year where the renewable energy potential condition changes by the time and the energy requirement for the pond changes as needed so that the fish grow optimally, and it is expected that the built system will be able to function throughout the year.

After calculating the duration of the aerator during the life cycle of the fish, and the need for lighting of the pond and home appliance, it can be concluded that the required load is like the figure 3, below.

3. Result

3.1. Plant setup

Because of the unstable wind potential and biomass potential, gasification provides a supply of electricity that can support fluctuating electricity to meet demand load. This is also to reduce the carbon footprint in the plant. In this research, wind energy as a non-dispatchable resource, and gasification serves as a dispatch-able resource. Figure 1 show the system of plant setup for simulation.

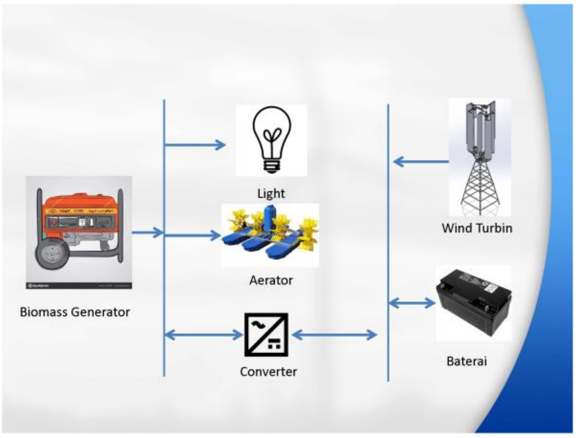


Figure 1. Plant set up in Homer

3.2. Analysis

The use of several windmill with specifications of the same capacity to see some of the possibilities of windmill configuration, setup fees, maintenance that eventually affect the LCOE, here there are 2 types of windmills that will be discussed. From result of simulation with homer got result as follows.

From simulation for optimization has 200 working combination of system for each type of wind turbine, and below is table 3 and table 4 for each 5 best combinations.

Table 3. Best combination for Aeolos 500

No	A 500	Label (kW)	L16 P	Converter (kW)	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Diesel (L)	Label (hrs)
1	9	2	24	10	$9,900	1,721	$31,894	0.447	0.86	430	705
2	9	2	22	10	$9,700	1,740	$31,948	0.448	0.85	460	770
3	8	2	26	10	$9,600	1,751	$31,984	0.449	0.83	488	786
4	9	2	26	10	$10,100	1,716	$32,031	0.449	0.87	408	657
5	10	2	22	10	$10,200	1,711	$32,074	0.45	0.89	388	663

3.2.1. Aeolos 500 wind turbine (wind 1)

Providing the largest power supply compared to other configurations, with the number of turbines 9 units.

Table 4. Best 10 combination for Sunnily

No	Sunily	Label (kW)	L16P	Converter (kW)	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Diesel (L)	Label (hrs)
1	12	2	24	10	$11,400	2,393	$41,986	0.589	0.62	931	1,464
2	4	2	5	10	$5,500	2,858	$42,032	0.59	0.22	2,024	4,168
3	12	2	28	10	$11,800	2,372	$42,127	0.591	0.63	882	1,374
4	12	2	22	10	$11,200	2,421	$42,154	0.591	0.62	966	1,548
5	12	2	26	10	$11,600	2,392	$42,181	0.592	0.63	919	1,436

Deficiency, the relative price per unit is expensive compared to other wind turbines and is rare to find in market. 8 units arranged in this 3 x 3 matrix requires an area of 45.9 m x 45.9 m. Providing the largest power supply compared to other configurations, with the number of turbines 8 units.

3.2.2. Sunily wind turbine (wind 2)
Providing a large power supply with a total of 12 units of turbines arranged in a 4 x 3 matrix requires an area of 51 m x 74 m. Due to a number of units more than wind 1 then LCOE (*Levelized Cost Of Electricity*) system is higher than the system that uses wind 1.

3.3 Recommended design
From the result of optimization by Homer, the system that can be recommended is shown in table 5 below.

Table 5. Configuration of renewable energy plant

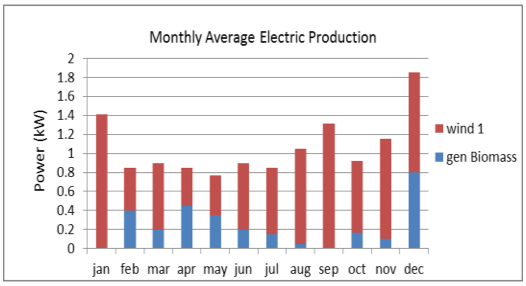
Renewable Configuration	wind 2	Wind 1
Wind turbine	12 Units	9 Units
Generator 1	2 kW	2 kW
Battery	24 Trojan L16P	24 Trojan L16P
Inverter	10 kW	10 kW
Rectifier	10 kW	10 kW

Table 6. Economic result of renewable energy plant

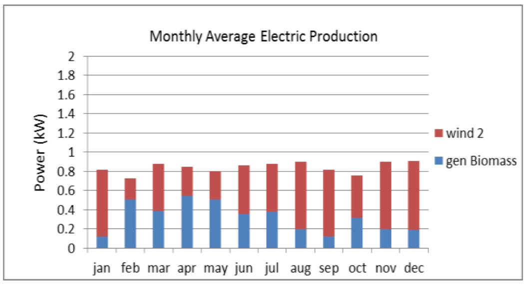
	Wind 2	Wind 1
Total net present cost	$41,986	$31,894
Levelized cost of energy	$ 0.589/kWh	$ 0.447/kWh
Operating cost	$ 2,393/yr	$ 1,721/yr
REN Factor	0.62	0.86

The cost and price of electricity that arise from the sistem and renewable energy factor for wind turbines shown in table 6.

Figure 2 shows that in some months from August to January the REN factor of the Aeolos 500 wind turbine exceeds 90%. In figure 3, in the months from August to January the REN factor of the Sunily wind turbine is only about 80%.



a.



b.

Figure 2. Comparison of energy generated by wind 1 (a) and wind 2 (b) with biogass generator

From the two types of systems with Aeolos 500 (wind 1) yield higher renewable energy factor and lower cost of electricity than systems using Sunily (wind 2).

4. Discussion

Optimization of solar power system has been done in Sleman Java, for aeration of fish pond and managed to get the appropriate system [21]. Evaluation of hybrid plants between solar and wind turbines has also been done for aeration ponds in Thailand [22]. Departing from the success of previous research is the author tries to make a hybrid generator between biogas and windmills for milkfish pond in Domas.

Comparison of several types of wind turbines and REN factor produced indicate that wind turbines in accordance with wind conditions will result in higher renewable energy factor [23]. In this study showed that the Aeolos 500 wind turbines is more suited and more optimum result to wind conditions at Domas, than the Sunily wind turbines. The two best design is feasible according to economic for area isolated from electricity such as milkfish pod in Domas.

For a capacity of 40 MW wind park hybrid with biomass gasification, Pérez-Navarro offers the concept of biomass gasification using syngas storage so that if the combustion process in the gasification reactor produces excessive syngas it can be stored, which can then be used when load needed is increased [9].

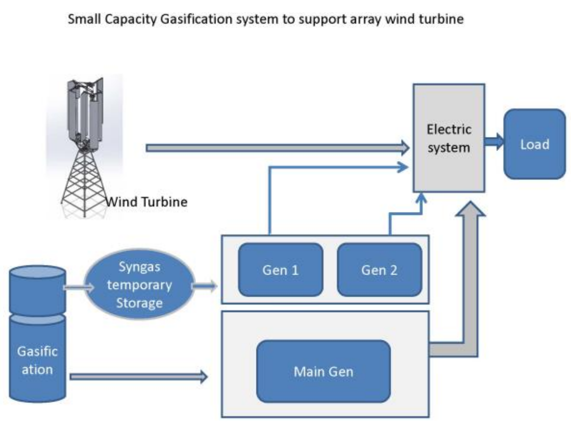


Figure 3. Proposed hybrid system of biomass gasification generator and array Wind Turbine

5. Conclusion

From the study that has been done, the recommended system of new renewable energy generation wind power using several wind turbines are feasible to build and have advantages and disadvantages of each. For overall electricity demand is 2.4 KWh per day for lighting and 13 KWh per day for aerators, with peak of 385watt and 1.9KW respectively.

It can be seen that *Aeolos* 500 in economic analysis, is cheaper and have higher the production rate of electricity than *Sunily* because of to the different power curve owned by each wind turbine. The more characteristic of the power curve at low wind velocity will be higher REN Factor value and will decrease the LCOE (*Levelled Cost Of Electricity*).

REFERENCES

[1] Rosen, A. and Y. Sheinman (1996). "The power fluctuations of a wind turbine." Journal of Wind Engineering and Industrial Aerodynamics **59(1)** 51-68.

[2] Schmidt J, Cancella R, Pereira Jr AO., 2016. An optimal mix of solar PV, wind & hydro power for low-carbon electricity supply in Brazil. *Renewable Energy*. **85** 137

[3] Bhandari B, Lee K-T, Lee CS, Song C-K, Maskey RK, Ahn S-H., 2014. A novel off-grid hybrid power system comprised of solar photovoltaic, wind, and hydro energy sources. *Applied Energy*. **133** 236

[4] Cau G, Cocco D, Petrollese M, Knudsen Kær S, Milan C., 2014. Energy management strategy based on short-term generation scheduling for a renewable microgrid using a hydrogen storage system. *Energy Conversion and Management*. **87** 820

[5] Gang L, Rasul MG, Amanullah MTO, Khan MMK. 2011. Feasibility Study of Stand-Alone PV-Wind-Biomass Hybrid Energy System in Australia. *Power and Energy Engineering Conference* (APPEEC), Asia-Pacific. 1

[6] Osmani A, Zhang J., 2014. Optimal grid design and logistic planning for wind and biomass based renewable electricity supply chains under uncertainties. *Energy*. **70** 514

[7] Schmidt J, Cancella R, Pereira Jr AO., 2016. An optimal mix of solar PV, wind and hydro power for a low-carbon electricity supply in Brazil. *Renewable Energy*. **85** 137
[8] Kolhe ML, Ranaweera KMIU, Gunawardana AGBS., 2015. Techno-economic sizing of off-grid hybrid renewable energy system for rural electrification in Sri Lanka. *Sustainable Energy Technologies and Assessments*. **11** 53
[9] Pérez-Navarro, A., D. Alfonso, et al. (2010). Hybrid biomass-wind power plant for reliable energy generation. *Renewable Energy* **35** 1436
[10] Bhattacharjee S, Acharya S., 2015. PV–wind hybrid power option for a low wind topography. *Energy Conversion and Management*. **89** 942
[11] Erwin, Erny Listijorini, Rina Lusiani, Tresna P Soemardi., 2015. Development of the third darrieus blade of Sultan Wind Turbine for low wind speed. *Applied Mechanics and Materials*. **758** 7
[12] Surjosatyo, A, Muammara, et al, 2017. Prevention Study of Sand Agglomeration on Fluidised Bed Combustor with Co-Combustion Method. *Chemical Engineering Transactions*, **56** 1273
[13] Surjosatyo, A., I. Haq, et al. 2017. "Effect of rice husk ash mass on sustainability pyrolysis zone of fixed bed downdraft gasifier with capacity of 10 kg/hour." *AIP Conference Proceedings* 1826(1): 020009.
[14] Kabalci E. 2013. Design and analysis of a hybrid renewable energy plant with solar and wind power. *Energy Conversion and Management*. **72** 51
[15] Veldhuis AJ, Reinders AHME. 2015.Reviewing the potential and cost-effectiveness of off-grid PV systems in Indonesia on a provincial level. *Renewable and Sustainable Energy Reviews*. **52** 757
[16] Bekele, G. and G. Boneya 2012. "Design of a Photovoltaic-Wind Hybrid Power Generation System for Ethiopian Remote Area." *Energy Procedia* **14**, 1760
[17] Ghaem Sigarchian, S., R. Paleta, et al. 2015. "Feasibility study of using a biogas engine as backup in a decentralized hybrid (PV/wind/battery) power generation system – Case study Kenya. *Energy*. **90** 1830
[18] Meteonorm (2015). Global Meteorological Database for engineers, planners, and education. Rosen, A. and Y. Sheinman 1996. "The power fluctuations of a wind turbine." *Journal of Wind Engineering and Industrial Aerodynamics.* **59** 51
[19] ELFANI, Maria. The Impact of Renewable Energy on Employment in Indonesia. *International Journal of Technology 2011*, [S.l.] **2** 47-55
[20] CHO, Kang-Pyo; JEONG, Seung-Hwan; PERWITA SARI, Dany. Harvesting Wind Energy from Aerodynamic Design for Building Integrated Wind Turbines. *International Journal of Technology,* 2011 [S.1] **2** 189
[21] Prasetyaningsari, I., A. Setiawan, et al. (2013). "Design Optimization of Solar Powered Aeration System for Fish Pond in Sleman Regency, Yogyakarta by HOMER Software." Energy Procedia **32** 90
[22] Nookuea, W., P. E. Campana, et al. (2016). "Evaluation of Solar PV and Wind Alternatives for Self Renewable Energy Supply: Case Study of Shrimp Cultivation." Energy Procedia **88** 462
[23] Yi, Z. and S. Ula (2008). Comparison and evaluation of three main types of wind turbines. 2008 IEEE/PES Transmission and Distribution Conference and Exposition.