IEEE 2020

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2020 2nd International Conference on Industrial Electrical and Electronics (ICIEE)

Feasibility Study for Development of Micro Grid System in Rural Island

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***Abstract*—Currently, the utilization of renewable energy is increasing for remote islands around the world including in Indonesia. In this paper, feasibility study regarding renewable energy resources to develop a micro grid system for Tangkeno, in Kabaena Island, southeast Sulawesi is done. Observed energy resources in this study include solar energy, wind energy, and micro-hydro. The capacity of the system is calculated to meet local electricity load until the next 10 years(the year 2028) which is around 120.150 kVA. From data and measurement, the potential of renewable energy for electricity production in Tangkeno is relatively good which can fulfill load demand under the studied period. It is promising to use renewable energy sources for developing a micro grid system as an alternative to meet local electricity needs.**

***Index Terms*—Feasibility, Micro Grid, Rural Island**

I. INTRODUCTION

Fossil energy such as coal and oil has been used as primary sources for energy power plants in Indonesia. According to the State Electricity Company (PT. PLN) [1], electricity energy production from energy from fossil is inefficient because of the high price of oil, expensive cost for construction, and carbon dioxide emissions. To reduce carbon dioxide emissions, renewable energy is used as alternative energy [2]. Studies of feasibility in various countries have been conducted [3, 4]. Each country has its own potential energy [5-7] and the global demand for renewable energy is increasing. Indonesia as a tropical country has abundant natural resources, such as wind energy, hydro energy, and solar energy. The use of renewable energy resources can be optimized by using micro grid technology that the capacity of the power grid and the efficiency can be increased [8]. The primary energy on a national scale can be listed as oil 48%, coal 31%, gas 17%, 2.3%, geothermal 1.1%, and renewable energy is lower than 1%. Therefore, in RUPTL 2016-2025 PT. PLN has plan development in Indonesia several regions of renewable energy sources [9]. Kabaena Island is one of the islands located in Bombana Regency, South East Sulawesi Province. Tangkeno is a remote area of Kabaena Island which currently cannot be supplied by the PLN grid. Therefore, alternative energy such as micro-hydro, solar energy, and wind energy is necessary to be applied. Geographical conditions of Tangkeno is a hilly area with a good potential of wind, solar and micro-hydro energy. The reliability of the microgrid is to lie in the balance of the electricity supply from its electrical needs. Then all systems connected to the plant must be monitored and measured and controlled in accordance with the targets achieved and optimize the use of renewable power plants in order to operate minimally [10]. In terms of potential, this study discussed and grouped in the first sections of a preliminary study of energy, and the governing energy resources rule in RUPTL 2016-2025. The second section is the potential for solar energy. The third is the potential of winds that can be converted into power plants. The fourth examines the potential of micro-hydro that can be converted into electrical energy. The fifth is the eligibility of the potential energy in Tangkeno that can be utilized as efficient energy and environmentally friendly sources.

II. MICROGRID SYSTEM

The process of determining the system configuration, combining the sources and the operating strategies are important to determine the power plants working properly. The configuration of a microgrid system, which contains several combinations of photovoltaic, wind turbines and hydro turbines as a source of renewable energy [11, 12]. Figure 1 shows the hybrid power schematic diagram of the three energy sources.

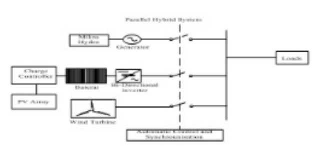

Fig. 1. The circuit diagram of the microgrid system

A. Wind turbine Equation

Wind power plants are one of the renewable energy power plants that are environmentally friendly and have good work efficiency. The principle of a wind power plant is to utilize wind energy that enters the turbine area to rotate a propeller or windmill, then produce energy to rotate a generator that can produce electrical energy. Wind power is the amount of energy that can be produced by the wind at a certain speed which will rotate windmills with a certain area [13]. The equations for determining the capacity of a wind turbine are as follows.

$$P = \frac{1}{2}\rho A V^2 \quad (1)$$

where
P = Power of mechanical (watt).
$\rho = Airdensity(kg/m^3)$.
A = The blades rotor area covered (m^2).
V = Wind speed (m/s).

TABLE I
WIND TURBINE OUTPUT PARAMETERS [12]

Parameter	Information
Average Output	The average amount of energy from a wind turbine for a year
Minimum Output	The minimum amount turbine energy output for a year of wind turbine.
Maximum Output	Maximum amount of wind turbine energy output for a year.
Capacity factor	Mean Output rated capacity.
Hours of Operation	The amount of time from the wind turbine during energy generation.

B. PV energy equation

Indonesia has solar radiation ranging from 4.66 to 5.34 kWh/m2/day and the eastern part has a radiation level of 4.85 kWh/m2/day. For this, it is modeled the PV arrays as a device that produces dc energy [14]. It can be calculated for the output voltage of the solar cell the equation using.

$$P_{PV} = F_{PV} Y_{PV} \frac{I_T}{I_S} \quad (2)$$

where
$F_{pv} = Derating factor of PV$
$Y_{pv} = Permitted power from PV (kW)$
IT = Surface of the PV array by solar cell (kW/m^2)
Is = Standard amount of radiation by PV capacity of the array (1kW/m^2)

Watt peak (Wp) is a unit of power generated by photovoltaic modules in the standard test condition (STC), or the amount of energy produced under the standard conditions of transmitting 1 kW/m2 and panel temperature of 25°C. The size of the PV array is always specified in the permitted portion of power capacity. Derating factor is a scale factor to calculate from dust effect on panel, losses on wire, temperature, or all factors causing the reduced output of solar cells from the expected condition. The solar cell output decreases with the increasing temperature on the panel, but the planner can reduce the derating factor to improve the situation in the hot climates.

C. Micro-hydro equation

A hydro turbine converts energy into ac electrical energy in a steady, Rush the flowing water is perfect for water turbines to produce considerable energy. The hydro turbine consists of the available head (m) about 15 m from the vertical distance between the pipe to the turbine. The design flow rate (L/S) is the average water flow per second 0.30 m3/s. The minimum flow ratio (%) is the maximum average of the incoming water flow to the turbine. Efficiency (%) is the average efficiency of a hydro system when converting water energy into electricity [15].

$$P = 9.8 Q H_n \eta_t \eta_q \eta_{tm} \quad (3)$$

where
P = Power (watt)
Q = Water disharge (m^3/s)
$H_n = Head\ falling\ water(m)$
$\eta_t = Turbineefficiency(0.80)$
$\eta_q = Generatorefficiency(0.9)$
$\eta_{tm} = Mechanical\ transmission\ efficiency\ (0.95)$

III. POTENTIAL OF POWER PLANTSIN KABAENA

Natural resources are supporting factors derived from nature to generate electrical energy. There are three kinds of natural resources, namely solar, wind and hydro. The natural resources can be updated depending on the location. The great solar source depends on the climate, the latitude is 5 o 1557.21 o S, longitude is 121 o 5711.04 o E and the scale is 1:100.000. The wind sources depend on the rainfall patterns and topography [16]. The available resources affect the process and the economic problems of the renewable energy system, as resources determining the amount of renewable energy production. Figure 2 shows the Tangkeno region on Kabaena island.

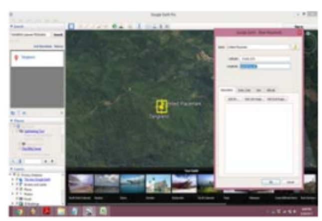

Fig. 2. Tangkeno region coordinat

A. Wind turbine energy source

System model for wind turbines, a planner should include wind energy data for 12 months or a year in a given area and 4 additional input parameters: Weibull shape factor, autocorrelation factor, the strength of patterns, and wind speed hour of a peak.

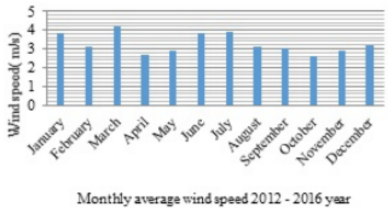

Fig. 3. Typical monthly average wind speed in the observed area for 2012-2016

Weibull is the measurement of the distribution of wind speed for a year. Autocorrelation is factor a large measurement speed of wind within an hour depending on speed wind at a previous hour. Wind turbine data are obtained from power.larc.nasa, for 6 (six) years in Tangkeno area at latitude is 5 o 160.53 o E and longitude is 121 o 5710.76 o S counted for 6 years the data [17].

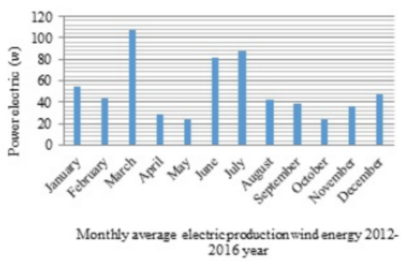

Fig. 4. Monthly electricity productionfrom wind energy for 2012-2016

B. PV energy source

The level of energy source potential must be identified by a planner when use solar/PV cells. Therefore, solar data from a predefined location are needed. Solar power sources is amount average of solar radiation (radiation of sunlight that leads directly to the surface of the observed place). The data consists of data on average hourly sun, the horizontal surface (kWh/m$^2/day$).

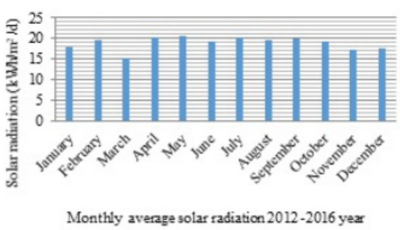

Fig. 5. Monthly solar radiation in the studied place for 2012-2016

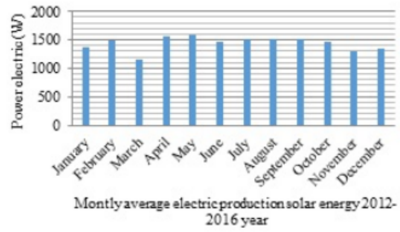

Fig. 6. Monthly production solar energy for 2012-2016

The source of solar energy is obtained from Tangkeno in a year, with an average of 9 hours of sunlight every day, 270 hours every month and 3.240 hours every year. In figure 2, the data can be determined by location (latitude longitude) and time zone or get data via the internet, by connecting to the internet and retrieve solar radiation data directly from the NASA site.

Solar Modul Capacity

$$= \frac{E_T}{Solar\,Inculation} Insulation = \frac{21.566Wh}{3.92} 1.1 = 6501.68Wp \quad (4)$$

C. Micro-hydro energy source

Source of flowing water in Tangkeno of South East Sulawesi is discharge water with the rate and amount of 0.30 m3/s of this potency which can be given at this flow. The conversion to electric energy can use Eq. (3) so this potency can be connected to micro grid at area Tangkeno South East Sulawesi to generate electricity for community needs with the power of 27.14 kW. To know the power generated from micro-hydro planning. The data for micro-hydro are obtained from measurement as shown in Table 2.

TABLE II
MEASUREMENT DATA OF MICRO HYDRO

Measurement of Flow Rate (m3/s)				Note
Measurement	Track Length (m)	Traveling Time (sec)	Speed (m/sec)	
1	5	3.23	1.54	
2	5	3.39	1.47	River Width 3.04 m
3	5	3.47	1.44	0.15 m Depth
4	5	3.55	1.40	
5	5	3.34	1.49	
Average			1.46	
Cross - Sectional Area A (m2)			0.456	

IV. RESULT AND ANALYSIS

Basically, a total electricity need is based on the condition of the socio-economic community at a related place. Particularly for the Tangkeno area, load composition including required electricity energy (assumption) based on the existing population and pubic facilities for the year 2018 are shown in Table 3.

From the table, the structure of the load consists of 170 houses, 2 school buildings, 1 community health center, 1 mosque, and 1 village office. If the electricity demand growth is set to increase 5% each year, then yearly electricity load until the year 2028 is given in Table 4 or graphically shown in Fig. 7. Next, as an initial step, the capacity of each renewable energy source for developing the micro grid system is calculated based on the load prediction.

TABLE III
ELECTRICITY NEEDS FOR TANGKENO AREA

No	Facility Type	Number of Unit	Electricity Energy Need (VA)	Total Energy For Each Facility (VA)
1	House	170	450	76.500
2	Elementary School	1	450	450
3	Junior High School	1	450	450
4	Community Health Center	1	900	900
5	Mosque	1	900	900
6	Village Office	1	900	900
Total				80.100

TABLE IV
PREDICTION OF ELECTICITY NEED FOR THE NEXT 10 YEARS

Year	Energy Need (VA)
2018	80.100
2019	84.105
2020	88.110
2021	92.115
2022	96.120
2023	100.125
2024	104.130
2025	105.135
2026	112.140
2027	116.145
2028	120.150

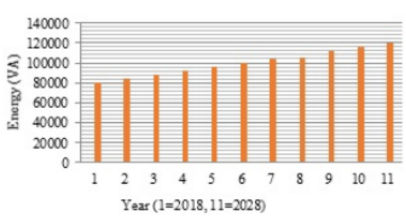

Fig. 7. Electricity needs prediction for the next ten years

From obtained data and measurements regarding water discharge, solar radiation intensity, and wind speed, then the potential of electricity generation for each source can be known as follows:

1. Wind energy

For wind energy, based on the data and by using Eq. (1), electrical energy that can be generated from one unit wind power plant is 134,29 VA.

2. PV energy

From data and by using Eq. (2), electrical energy that can be generated from the solar power plant is 1,970.02 VA.

3. Micro-hydro energy

For the micro-hydro system, based on the measurement data and by using Eq. (3), electrical energy that can be produced is around 33.925 kVA.

Based on the calculation and analysis results, the potential energy of the Tangkeno is extremely big. The potential of a single installing wind turbine energy is 134.29 VA the harvesting energy from Solar PV is 1.970 kVA and the potential of micro-hydro is 33.925 kVA. There are for the total energy from the three renewable energy sources is 36.029 kVA Illuminate the number of loads in which 170 families and total load of 80 kVA load data prediction for the next 10 years (2028) is 120.150 kVA. The predictable need for the next 10 years (2028) is 120.150 kVA. From the results of calculations obtained, there is still a lack of energy to supply the existing load in Tangkeno around 84.121 kVA. Investment to build wind turbines of around 10 units with a capacity of 1.34 kVA and to build Solar PV around 42 solar panels with a capacity of 83.74 kVA needed to meet electricity need 42 solar panels with a capacity of 83.74 kVA needed to meet electricity needs

V. CONCLUSION

The process of determining the system configuration, combining the sources and the operating strategies are important to determine the power plants working properly. The configuration of a microgrid system, which contains several combinations of photovoltaic, wind turbines and hydro turbines as a source of renewable energy [11, 12]. Figure 1 shows the hybrid power schematic diagram of the three energy sources.

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