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The Innovation Breakthrough in Digital and Disruptive Era

Design of a Loadbased Battery Discharge System in a Remote Island Using Marine Currents and Solar Energy as Energy Sources

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Abstract. This paper proposes a plan of electric system on a remote island that utilizes the power of marine currents and solar. The supply system is carried out in a decentralized battery and a centralized battery. The types of batteries used is Lithium-Ion (Li-Ion). The decentralized battery system and the centralized battery, refer to each customer's load power. Power customer loads using DC (Direct Current) equipment and lighting. The battery voltage used as a source is 48 V while the customer uses 12 V. The use of batteries as the main source to meet the electricity needs of various types of customers uses a maximum current of about 3.8 A.

Keyword: Battery, Marine current, Solar energy, Direct current, Load

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1 Introduction

Fulfillment of electricity in remote areas requires new and continuous innovation. Electricity in remote areas is generally supplied using energy sources from diesel generators which will cause air pollution. Other energy sources come from renewable energy sources such as wind, photovoltaic, marine currents and waves [1] [2].

In the operation of renewable energy sources, batteries are needed because of the nature of renewable energy sources which are intermittent, affected by temperature, and fluctuate [3]. Batteries are needed to meet the electricity needs in order to remain continuous. The characteristics of the battery used are assessed based on the parameters used. Related parameters include the quantity of energy that can be stored, discharge, voltage rating, battery capacity, battery life, number of cycles and temperatures.

On the other hand, many electronic equipment uses DC (direct current) voltage which allows batteries to be used to operate the equipment and lighting. The battery-based DC house design project can be started from renewable energy sources available in remote areas. The DC house aims to improve the lifestyle for residents who do not have access to electricity

Some of the advantages of using DC home are that it can directly provide energy savings, low environmental costs, and more efficient use of equipment. Other advantages presented by [4] that the use of photovoltaic (DC) which is directly distributed to all household appliances will save between 9% to 20% and can save energy by 14-25%. Therefore, state search around 35% of all energy consumption at home are appliances, electronics and lighting, all of which can work on DC. The direct use of batteries in households and public facilities on a remote island on a certain scale will be the concern and discussion of this paper. The use of batteries directly considers several factors, namely the potential of energy resources to charge the battery, load patterns, battery types and network design needed to maintain the continuity of their use.

2 Methodology

2.1 Design of Sources

Two sources will supply electrical energy to the battery. Marine currents power plants and solar power plants are hybridized to support each other as a source of electrical energy at all times. Marine current energy is an energy source that can be used to drive a turbine and coupled with a generator to generate electricity.

A mathematical approach that formulates the power produced from a flow of fluid going through a surface A in a direction perpendicular to the transversal surface. The amount of electrical energy created follows the equation. [5]:

$$P_{MC} = 0.5 \cdot \rho \cdot v^3 \cdot C_p \cdot A \quad (1)$$

Where P is the power generated, Watt. ρ is the density of seawater, 1025 kg.m^{-3} . C_p is the power coefficient, its value in this paper is 0.35. The value of C_p represents the area percentage of the resultant power of the fluid flow. A is the turbine coverage area, m^2 . v is the speed of the marine current, m. S^{-1} .

The potential for solar energy in the equatorial region is very supportive to be used as electrical energy. Utilization by using photovoltaic which can be arranged in series or parallel. The power that can be generated by photovoltaic based on the intensity of radiation received by the panel is [6]:

$$P_{PV} = \eta \cdot S \cdot I \cdot (T_a - 25) \quad (2)$$

Where η is the conversion efficiency of PV cells, S is the surface area of the PV surface, I is the solar radiation and T_a is the ambient temperature ($^{\circ}\text{C}$).

The configuration of the marine, photovoltaic (PV) and battery electricity generation system will produce a total energy source (P_{TS}) as an equation. [7]:

$$P_{TS} = P_{MC} + P_{PV} \quad (3)$$

P_{MC} = electric power from ocean current source, Watt

P_{PV} = electrical power from solar panels, Watts

Electrical energy, Watt hour (Wh), equation (3) is integrated with time:

$$E_{TS} = \int P_{TS} dt \quad (4)$$

2.2 Design of DC Network

Electrical energy is generated by marine currents due to the motion of a turbine coupled to a generator. The generator will generate electricity. The electricity generated is converted to DC electricity by means of an AC-DC converter. Likewise, the electricity generated by the photovoltaic generator is converted to the appropriate DC using a DC converter. DC electricity generated by both types of generators is channeled to the DC bus and then channeled to charge the battery [8]. The system configuration schematic is illustrated in Figure 1.

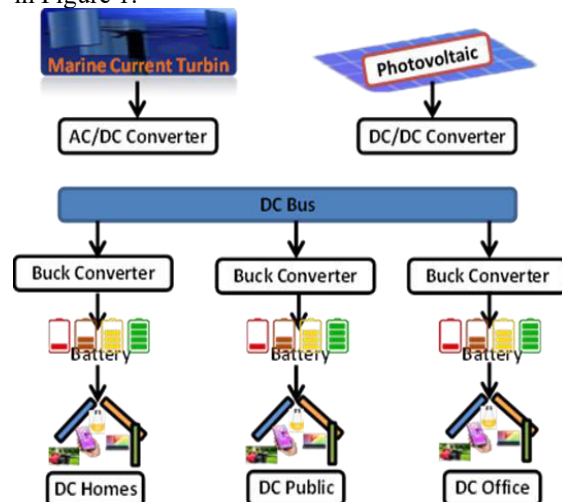


Fig.1. Configuration system

The battery is an electric cell consisting of two kinds of electrode plates, namely the positive electrode and the negative electrode and an electrolyte solution as a conducting medium. The electrochemical process from the three components of the battery produces electrical energy.

To charge and discharge the battery, identification of the battery is required. Battery identification to support system accuracy during charging and discharging [9][10]. The amount of energy that can be stored by a battery is formulated as follows:

$$E_{Bat,Max} = C_{Bat} \cdot V \quad (5)$$

Where $E_{bat, max}$ is the maximum energy that can be stored by the battery (Wh), C_{bat} is the battery capacity (Ah), and V is the nominal voltage of the battery (V). The formula shows that it is not necessarily the case that a battery with a larger capacity will have a greater maximum energy capacity than a battery with a smaller capacity but with a higher voltage.

The duration of the battery discharge (t_{disch}) is highly dependent on the battery capacity (Ah), percent DOD (% DOD) and load current (i_L) as the following equation:

$$t_{disch} = \frac{\%DOD \cdot Ah}{i_L} \quad (6)$$

DOD (Deep Of Discharge) describes how much discharge or how much battery has been used.

The operating voltage of the battery used is adjusted to the voltage of each equipment. The voltage of each equipment in this study uses direct current (DC) voltage. Currently, equipment in DC voltage is easily found in the market. The converter, a DC step-up/ step-down or coupled with inverter is widely provided in a package with an affordable price in the market. The main consideration for choosing a DC-based power system because it can offer attractive advantages in terms of simplicity, cost, and efficiency.

Factors that support the use of DC systems are DC generation and storage, increasing number of DC electronic devices in buildings and homes, use of electric vehicles (EV) which will increase consumption of DC devices (batteries), efficiency (in DC there is no skin effect on conductors), reduction of conversion stage which avoids unnecessary DC to AC and AC to DC conversion (energy wastage).

3.3. Results and Discussions

3.1 Sources Characteristic

The potential energy of marine currents and solar can be used as the main energy source and as a battery charger energy source.

From the graph in Figure 2, it can be seen that the power generated by the marine current turbine has 3 peak times, while from photovoltaic it has 1 peak time.

The resulting peak times support each other to meet the needs of the electrical load. The maximum power generated is 875686.749 Watt at 04.00 am. The minimum power occurs at 02.00 pm which is 2.584 Watt.

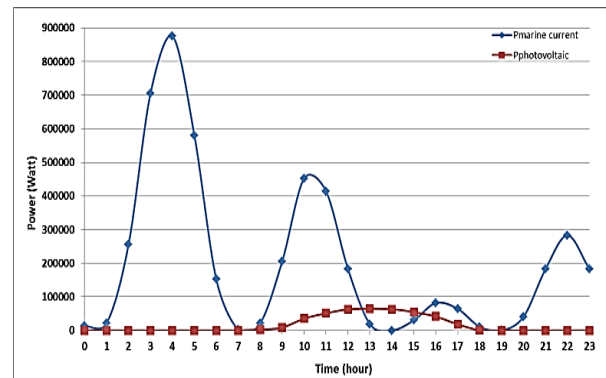


Fig. 2. Electricity from marine and solar power.

In this study, the turbine diameter is 3 meters was used. Whereas in photovoltaic, if the average temperature used is 31°C, panel efficiency = 25%, table 3 then the amount of electrical power produced by solar panels is based on equation (2) as shown in Figure 2:

3.2 Loads Characteristic

The load calculation is taken from each power of the equipment used. All household appliances in this study use a DC (direct current) system.

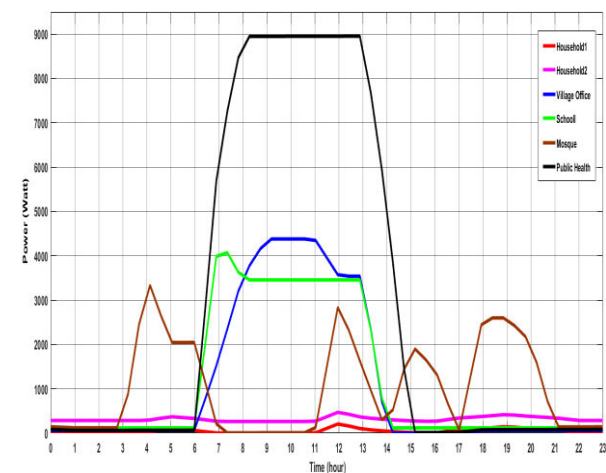


Fig. 3 Load profile by customer category

The category of public health users (6) is the highest use of electrical energy, which is 66179 Wh, while the lowest is household category 1 (Household1) which is 1156. Maximum electrical energy occurs at 08.00 am to 13.00 pm.

3.3 Loads fulfilment

To identify load requirements, it is necessary to describe the detailed requirements of each equipment used. Determination of the load of

each equipment is identified from the voltage, power and voltage used. Based on the load on each customer, the total energy required for each customer category is calculated. The total electrical energy in table 3 that customers use depends on the amount of equipment used and the power (watt) of each equipment.

Measurement of electric current and voltage is carried out in 2 conditions of battery placement, namely scattered batteries and centralized batteries.

The electric current measurement is done by connecting a 48 V battery to each customer via a DC converter. One of the measurement results is carried out on category customers where the source of the battery used is Lithium Ion (Li-Ion). The results of the measures are presented in Figure 4. The maximum current is 3.8 A.

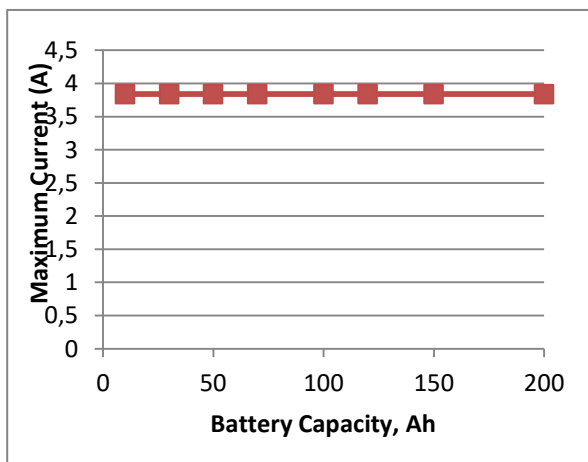


Fig.4. Maximum current of 48 V Li-Ion battery.

The voltage will decrease as the DOD value increases, although it is not linear. Based on the measurement results from the simulation conducted on 6 categories of customers. The DOD status of lead acid has a faster increase in DOD, followed by Ni-mH and finally Li-Ion. Battery life is directly related to how deeply the battery is used in each cycle. If each cycle is only 10% Depth of Discharge then the battery life will be five times longer when compared to that used at 50% DOD.

4 Conclusion

Marine current-PV-battery power plant planning has been carried out. Power from ocean currents and PV is distributed to each customer category with a DC (direct current) system. For each customer category, a battery is provided as a




backup. The current characteristics of the battery are displayed as a form of electricity being distributed to each customer. The results show the characteristics of the speed of ocean currents and photovoltaic which can support electricity supply in remote areas.

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