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Development of solar cell and fuel cell integration model and economic analysis in on grid and off grid system.

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Abstract. Electricity has become a very important needs for human life today and one of the parameters in one region condition. Nowadays, the dependence on fossil fuels to fulfill the electricity needs is really worrying, and it causes the depletion of fossil fuels. Today, the whole world is paying more attention to renewable energy as one of the best solution to solve the future energy problems. Renewable energy becomes the best solution because it will not be exhausted and enviromentally friendly. In the other hand, renewable energy also have problem, because it cannot produce energy everytime like photovoltaics which can produce energy only when there is enough solar radiation. Therefore, a hybrid system is made that expected to minimize the weakness from other components of the system . In this project, a hyrid system is designed using HOMER PRO software to calculate the electricity and economic factor of the hybrid system. The objective of this project is to find the best hybrid system that can solve the electricity problems. The system will be independent since grid function will replaced by fuel cell in the 19th year based on the assumption.

1. Introduction

Electricity has become a very important needs for human life today and one of the parameters in one region condition. Nowadays, the dependence on fossil fuels to fulfill the electricity needs is really worrying, and it causes the depletion of fossil fuels. Today, the whole world is paying more attention to renewable energy as one of the best solution to solve the future energy problems. Renewable energy becomes the best solution because it will not be exhausted and enviromentally friendly.

In the other hand, renewable energy also has drawbacks, since it cannot produce energy everytime like photovoltaics which can produce energy only when there is enough solar radiation. Therefore, a hybrid system is made that expected to compensate the weakness from renewable energy components of the system.

On this day, generator are still being the most commonly used component as a back up in hybrid system especially in Indonesia. As we know, generator is using fossil fuels, so it is not friendly enough for environment because of its pollution. So, the objective of this paper is how to familiarizing fuel cell latest system as back up power in Indonesia and finding the best hybrid system model using fuel cell as back up which can solve the electricity problems.

For the proposed hybrid system, the meteorological data of solar energy is taken for Depok, Indonesia (Latitude 6˚23'N and Longitude 106˚49'E). This paper is used two kind of load profiles, residential and commercial load profile that modeled using Hybrid Optimization Model for Electric Renewable (HOMER) software. The main source of power is Photovoltaic system, and the back up system is Fuel Cell.

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2. System Components

A. Photovoltaic System

Solar Cell panel initial cost and replacement cost are Rp. 11,000,000 / kilowatts. The monthly clearness index and radiation are obtained from NASA and shown in table I.

Table 1. Monthly Solar Radiation and Clearness Index

Month	Clearness Index	Daily Radiation ($kWh/m^2/day$)
January	0.224	2.392
February	0.289	3.111
March	0.443	4.655
April	0.576	5.672
May	0.702	6.339
June	0.795	6.809
July	0.752	6.575
August	0.640	6.050
September	0.504	5.141
October	0.363	3.848
November	0.248	2.637
December	0.208	2.200

B. Fuel Cell

Fuel Cell is a component that uses methanol as fuel. Methanol will converted into hydrogen in reformer, then hydrogen will converted into electricity. The initial capital and replacement cost of 5 kw fuel cell are 400,000,000 rupiah.

C. Inverter

Inverter is used to convert the solar cells and fuel cells energy production from DC bus into AC bus. The initial and replacement cost from inverter are 4.225.000 rupiah.

D. Battery

Batteries are used to store energy that produced by photovoltaic system. Battery that used in this simulation is IND13-6V Trojan battery. The IND13-6V parameters are shown in table 2.

Table 2. Battery Parameters

Properties	Trojan IND13-6V
Nominal capacity	951 Ah
Nominal voltage	6 V
Round trip efficiency	80 %
Min. State of charge	20 %
Max charge rate	1 A/Ah
Life throughput	7.186 kWh

E. Grid

In this paper, it is assumed that net metering system is not used, so it cannot sell the energy that has been produced. The electricity price of the grid is 1,467 rupiah/kWh.

3. Load Profile

This simulation uses residential and commercial load profile model. Residential load is used for off grid system, while commercial load is used for on grid system. Hourly load profile of residential and commercial are shown in Figures 2 and 3.

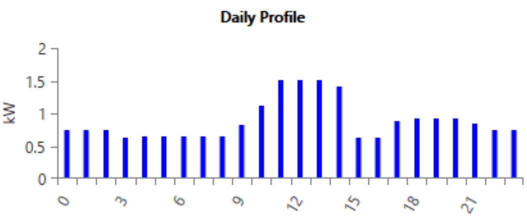

Fig. 1. Residential Hourly Load Profile

Fig 2. Commercial Hourly Load Profile

4. Methodology

HOMER Pro simulation is used to create the system modeling and simulation. On grid and off grid model are used in this simulation. The initial capital for these simulations are shown in tables 3 and 4.

Table 3. Cost Of Summary On Grid System

Component	Rating	Total Cost (IDR)
Solar Panel	30 kW	Rp. 330.000.000
Fuel Cell	5 kW	Rp. 400.000.000
Inverter	20 kW	Rp. 84.500.000

In On Grid System, Photovoltaic and Fuel Cell are used to reduce grid energy consumption. The lifetime of the project is 20 years. Discount and inflation rate are 5.30 % and 3.18 %. It assumed that load will increased 5% per year, electricity and methanol price will increased 7% and 1% per year, and Photovoltaic ability to produced power will be degrate 0.5 % per year. On grid simulation are shown in figure 3.

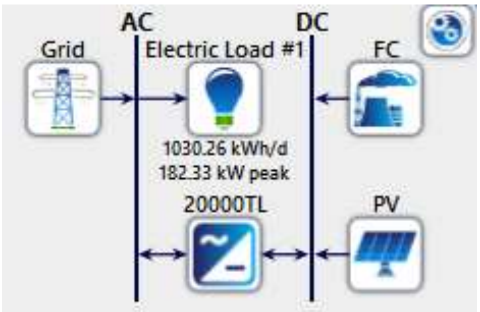

Fig. 3. On Grid System Simulation Model

Table 4. Cost Of Summary Off Grid System

Component	Rating	Total Cost (IDR)
Solar Panel	7 kW	Rp. 77.000.000
Fuel Cell	5 kW	Rp. 400.000.000
Inverter	3 kW	Rp. 12.675.000
Battery	6 V, 7.186 kWh	Rp. 51.840.000

In Off Grid System, Photovoltaic will be a main source and Fuel Cell are used to be a back up power. The lifetime of the project is 10 years. Discount and inflation rate are 5.30 % and 3.18 %. It assumed that load and methanol price will increased 5% and 1% per year. Off grid simulation are shown in figure 4.

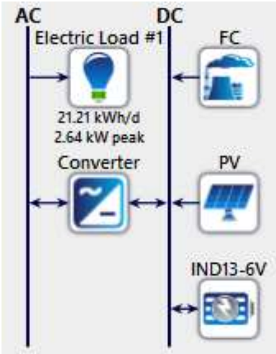

Fig 4. Off Grid System Simulation Model

5. Optimization and Simulation Result

On grid system optimization result is shown in Figure 5. It illustrates the optimum rating of each components. In figure 6, it describes a commercial load profile change for 20 years, and energy productions from the components over 20 years are shown in figure 7 – 9.

Architecture			
PV (kW)	FC (kW)	Grid (kW)	Converter (kW)
30.0	5.00	999,999	20.0

Fig 5. On Grid Optimization Result

Fig 6. Commercial Load Profile Change in 20 Years

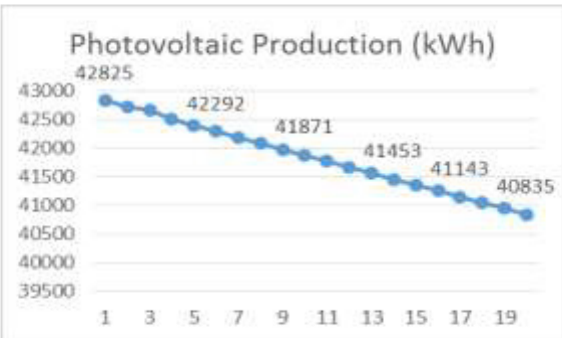

Fig 7. Photovoltaic Production in 20 Years

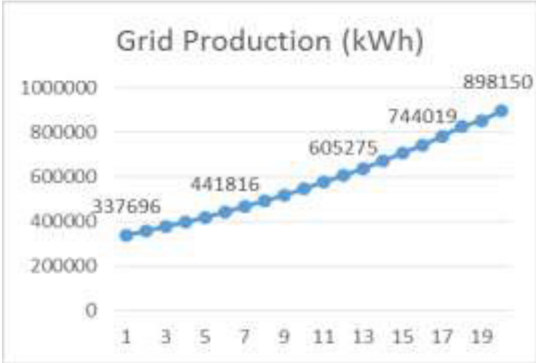

Fig. 8. Grid Production in 20 Years

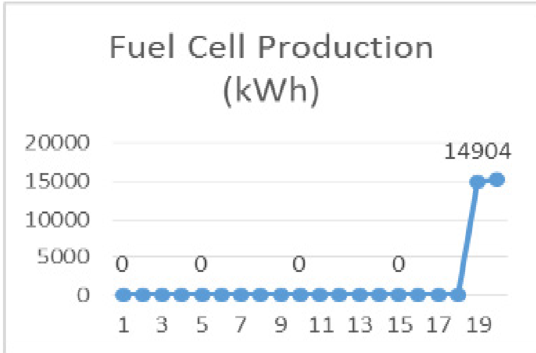

Fig. 9. Fuel Cell Production in 20 Years

Off grid system optimization result is shown in Figure 10. It ilustrates the optimum rating of each components. In figure 10, it describes a residential load profile change for 10 years, and energy productions from the components over 10 years are shown in figure 11.

Architecture			
PV (kW)	FC (kW)	IND13-6V	Converter (kW)
7.00	5.00	24	3.00

Fig. 10. Off Grid Optimization Result

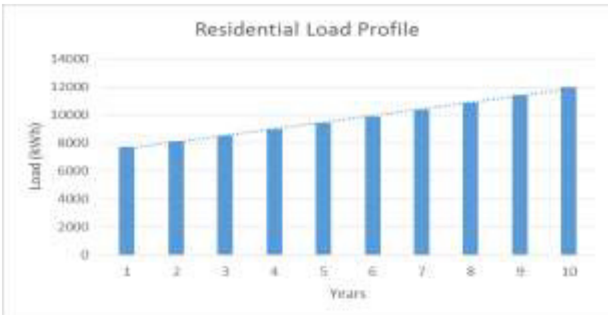

Fig. 11. Residential Load Profile Change in 20 Years

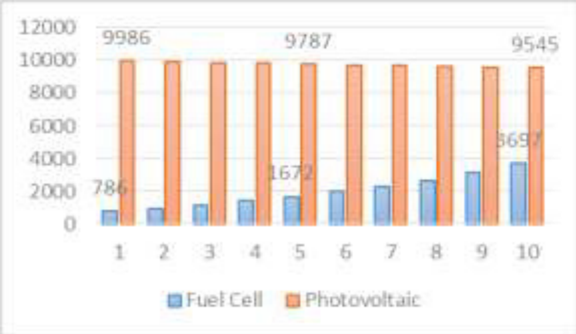

Fig. 12. Photovoltaic and Fuel Cell Production

6. Result and Conclusion

The results of on grid dan off grid system are obtained from the model that has been made before. Table 5 ilustrates a cost analysis of hybrid model, and figure 13 shows a cost spent for grid purchases in 20 years in on grid system.

From the simulation, it describes that levelized cost of energy and fuel cell year are affected by some variables. Figure 13 and 14 illustrates the variables that affected the levelized cost of energy from on grid and off grid system. The variables that affected fuel cell year are shown in figure 15.

Table 5. Cost Analysis of Hybrid Model

Hybrid RES	On Grid System	Off Grid System
Initial Capital	814.500.000	541.515.000
Operating Cost	1.814.904.000	2.161.812
Total NPC	30.334.830.000	522.151.781
Total COE	2.992	5.993

Fig. 13. Grid Cost in On Grid System

From the curve above, it shows a gap between grid only and grid intergated with solar cell and fuel Cell cost. That gap illustrates the saving cost when solar cell and fuel cell installed in system. Solar cell and fuel cell are installed in on grid system to reduce a grid cost. In on grid system, break even point will occur in the 12th year.

Fig. 14. Tornado Chart of LCOE (On Grid)

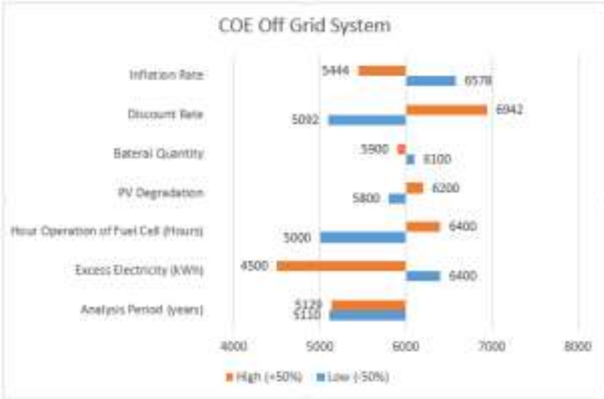

Fig. 15. Tornado Chart of LCOE (Off Grid)

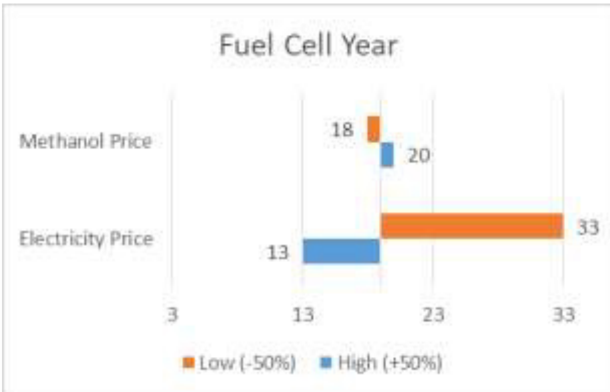

Fig. 16. Tornado Chart of Fuel Cell Year

In conclusion, In off grid system model, fuel cell as alternative energy do not polluting the environtment and has a low maintenance cost. It shows that fuel cell with its realibility can minimize the drawback of fluctuating renewable energy like solar cell to fulfill the energy needs.

Futhermore, the variables which most affected the levelized cost of energy are considered. In on grid system, system period and electricity price are the variables that affected the levelized cost of energy the most. In off grid system, levelized cost of energy are affected the most by excess electricity and operational hour of fuel cell. Then, based on those variables, its off grid model can be used as model that using fuel cell as back up to replaced generator.

In on grid system model, the time that fuel cell can replace grid function are affected by the increasing of methanol and electricity price. Its time will be longer when the electricity price escalation decreased and the methanol price escalation increased, and it will be shorter when the electricity price escalation increased and the methanol price escalation decreased. Lastly, based on the simulation result, fuel cell will replaced grid function as back up power in hybrid system model in 19 years.

Then, this kind of nano grids model with fuel cell as back up power will be the best solution to resolve electricity problems especially in remote area that unreachable with grid system.

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