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The Study of Potential Use of PV Pump For The Rain-Fed Rice Land In Simeulue Island by Using Homer Simulation

The Study of Potential Use of PV Pump For The Rain-Fed Rice Land In Simeulue Island by Using Homer Simulation

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Abstract. Simeuleu is one of the districts in Aceh Province which is located in the outer territory of the Unitary State of the Republic of Indonesia. In general, communities in districts with island clusters consisting of 147 large and small islands rely on agriculture and fishermen. One of the agricultural sub-sectors that is the main concern of the government is food, especially rice as the staple food of the community. Limited land resources supported by appropriate and adequate infrastructure have resulted in this business experiencing serious challenges and constraints. Of the available rice field area, 43.11% is rainfed lowland. During this time to irrigate some of the land, the potential of rainfall owned is considered able to meet the water needs of rice crops. However, the emergence of global climate change symptoms has led to cultivation efforts that rely on rainwater alone can not be expected completely. The irrigation technology of PV pumps has excellent prospects for the future of agriculture especially the food sector. This technology is very cheap for long term and also simple so easy to make and modified by anyone. PV pump irrigation does not require the operator to operate it, it is only necessary once check and control. The main benefit of solar irrigation technology development is to maintain environmental sustainability because it does not produce air pollution so that it can suppress the increase of global warming.

1. Intoduction

Solar energy is most abundant source of energy in the world. Solar power is not only the answer to the current energy crisis but also an environmentally friendly form of energy. The photovoltaic generation is an efficient approach to using solar energy. Solar panels (the arrangement of photovoltaic cells) are now widely used to run the street lights, to turn on the water heater, and others. The domestic cost of solar panels continues to decline, which encourages increased use in various sectors. One application of this technology is used in irrigation systems for agriculture [1]. Solar irrigation system can be an appropriate alternative for farmers in a state of energy crisis in Indonesia which is environmentally friendly green energy.

The solar irrigation system is a system that can effectively contribute to the conservation of vacant and unproductive lands. It is usually used PV to produce direct energy from solar radiation to generate a pump irrigation system. Utilization of vacant land can increase productivity and income of local farmers. The application of solar irrigation is closely related to the condition of water resources and local area [2]. Thus, knowledge of water sources and geographic conditions of the site is necessary for a study. PV pumping is now being applied for different uses in many regions. For instance, a PV pumping project in South Morocco was begun in 1997, and by 2005, the project had already reached 18 villages, affecting 15,000 people with total involved photovoltaic power is 46 kWp, and the total

volume of pumped water since the installation of the systems approaches 0.7 x10^6 m^3. PV-powered pumping is also eveluted in Bantul, Indonesia, where needed power 800 Wp to discharge 3.8 m^3/hr [3]. PV pumping technology also used in Saudi Arabia in supplying sufficient quality water [4]. Nowadays, PV pumping irrigation is being applied for the conversation of pastures in many parts of the world. At the same time, solar energy is being used in grassland pumping for over 25 years in Namibia [5]. The results show that PV pumping can operate longer and more effectively compared with traditional irrigation measures. The system also directly improves quality of life and promotes socio-economic development in that area [6].

The application of this technology that has application in Mexico and German also demonstrates that solar energy pumping produces more benefit and less pollution. PV systems for the pumping of groundwater are also used in Upper Egypt, proving that the cost of the water unit pumped by PV systems is significantly lesser than that pumped by diesel systems. [7] has discussed the potential for solar water-pumping systems in India and got the conclusion that solar photovoltaic systems are suitable in areas where cheaper sources of energy are not available. The research and application of solar irrigation system in China has not caused widespread concern. The application of solar powered irrigation has significant meanings in China, especially in Northwestern China. For the distribution of water resources is uneven and the precipitation is scare in that region. At 2016, it was evaluated performance of groundwater irrigation system by using solar water pump with 51 solar panels covering area of 120 m^2. Evaluation results of the technology application shows that solar energy can generate 7,873.5 watts. And maximum discharge 14.17 liter/second [8].

2. Literature Review

The solar power pump irrigation system is a system that can effectively contribute to the conservation of vacant and unproductive lands. Utilization of vacant land can increase productivity and income of local farmers. According [2] the application of solar irigation is closely related to the condition of water resources and local area. Thus, knowledge of water sources and geographic conditions of the site is necessary for a study. [2] also mention some indicators to be considered in solar irrigation systems. Among others are rainfall, land slope, temperature, solar radiation:

i.   Appropriate rainfall for solar power irrigation.
ii. The need for irrigation water is very dependent on rainfall. Rainfall must be higher than the water requirement.
iii. Appropriate slope for solar irrigation systems
iv. Tilt is closely related to the feasibility of solar irrigation. Tilt should not be more than 2-5% for groove irrigation and it should not more than 0.2% for closed irrigation.
v.   Temperature suitable for irrigation of solar power
vi. Temperature changes result in evaporation and transpiration changes and greatly affect crop water requirements. Higher temperatures will increase crop water requirements and increase pressure on photovoltaic pumps.
vii. Solar radiation suitable for solar power irrigation. Solar radiation is one of the important indicators for solar irrigation systems because it is an energy source for solar powered pumps. Large solar radiation is a guarantee for the application of solar irrigation systems. The sun exposure rate should be above 30%.

3.   Methodology

This research was conducted in two stages of activity. The first phase is a feasibility survey of the development area includes the potential of solar radiation and ground water which is a very crucial consideration in this research. The second stage is a simulation of the utilization of solar energy as a source of energy driving the water pump. The simulation is done with case study of pump usage to pump water into the maximum 50 meter pump head storage tank. The simulation is created by using HOMER software. In the optimization process, HOMER simulates each configuration system in search space and is displayed in a table, sorted by total net present charge (NPC). Figure 1 illustrates the solar-water pump system and its components. The solar radiation data for the simulation on the program is taken from the results of direct measurements to the field and validated with data from NASA satellites.

3.1. Research procedure

1. Survey of the feasibility of the development area by reviewing the availability of rice fields in the research sites supported by: wetland area data and irrigation field data.
2. Potential of solar energy:
    a. Measurements of solar radiation at the study site for approximately 1 month using a solarimeter radiation instrument
    b. In one day, there are three times measurement, morning (8.00 s.d 9.00 pm), noon (20.00-13.00 pm), and afternoon (16.00-17.00 pm)
    c. Measures the average duration of solar irradiance in a day.
3. Potential groundwater; to identify the potential of ground water, geoelectric apparatus is needed to obtain the resistivity value of rocks and minerals in the soil at the study site.
4. Land suitability; measuring the land topography
5. Simulation of HOMER

    Beginning with the determination of pump loads, determination and selection of types and prices of solar panels, batteries and converters, then input solar radiation data. Input data as follows: interest rate 4.25%, 500 watt inverter = Rp. 600.000 = $ 45, Trojan battery T-105 = Rp. 2.650.000 = $ 197, solar panel 100wp = Rp. 1,200,000 = $ 89.

3.2. Configuration of PV pump Irrigation System

The solar powered pump irrigation systems designed in this study (figure 1) include solar cell modules, pumps, batteries, storage (tanks) and converters. The basic principle of this PV pump's irrigation system works is: solar cells absorb sunlight, then generate electrical energy in the form of DC current stored to battery, go into converter to be converted to AC current, so move pump to suck water in tank. Water in the tank is used to meet the needs of the suboptimal land.
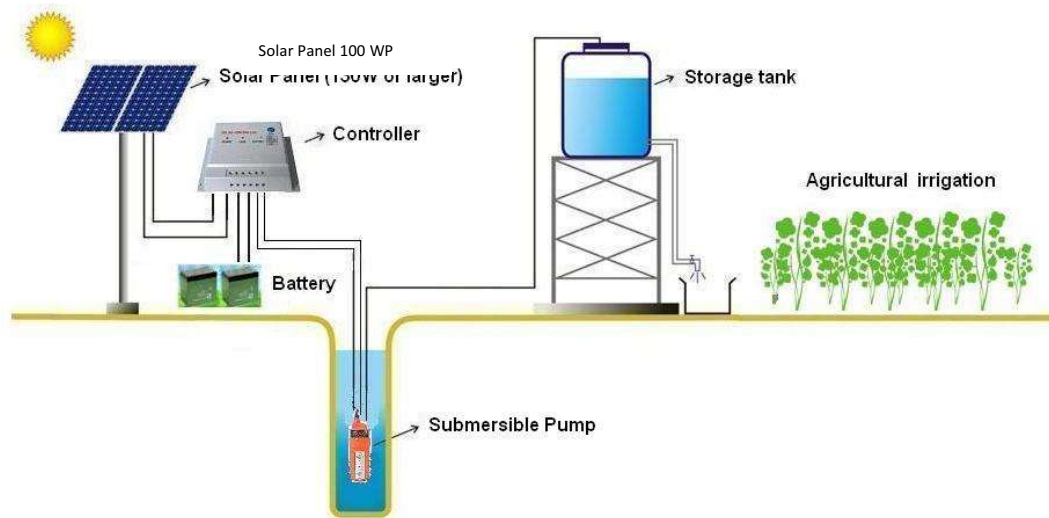

Figure 1. Scheme of solar power pump irrigation system (USDA and NSCR,2010).

3.3. Structural and functional design

3.3.1 Solar panels. Solar panels or modules serve to absorb sunlight and generate direct electric current (DC). Solar panel used is Solar Panel 100 Wp Shinyoku Polycrystalline with specification:

    i.   Maximum Power (Pmax) : 100 W.
    ii. Type Cell   : Polycrystalline
    iii. Voltage at Pmax (Vmp) : 17.5V

   iv.   Current at Pmax (Imp)   : 5.71A
   v.   Short circuit current (Isc): 6.4 A
   vi.   Open circuit voltage (Voc): 21V
   vii.   Maximum system voltage: 1000V
   viii. Number of cells   : 36 cells
   ix.   Dimensions + - (mm) : 1085 x 675 x 25
   x.   Weight (kg)   : 7.55

3.3.2 *Pumps and inverters*. The PV pump system consists of a PV generator, the electrical nominal Pel, a pumping motor unit that incorporates a motor and a pump (MP) and an inverter (INV) as conditioning power for generating PV.

3.3.3 Storage. Batteries are usually not recommended for solar-powered pump irrigation systems because they can reduce the overall efficiency of the system and increase maintenance costs and instead of storing electricity in batteries, it is generally simpler and more economical to install 3 to 10 days of water storage. This study designed two models, namely those that use batteries and do not use batteries considering the daily solar radiation research location that is not always there.

3.3.4 *Water tank, battery and solar charger controller.* Batteries were used in this study with consideration of daily solar radiation research sites that did not always exist. Battery used Battery Trojan T-105. Solar Charge Controller is a component in the PLTS system functioning as a regulator of current (Current Regulator) both to the incoming currents of the PV panel as well as outflow / use outflows. Works to keep the battery from overcharging (over charge), It regulates the voltage and current from the solar panel to the battery. Most Solar PV 12 Volt produces a voltage out (V-Out) of about 16 to 20 volts DC, so if there is no regulation, the battery will be damaged from excessive charging which is generally 12Volt battery requires charging (Charge) around 13-14, 8 volt (rely on battery type) to be fully charged.

4.   Results and discussion

4.1 Feasibility study of the development area

According to data from Simeulue Agriculture Agency, the area of rice field in Simeulue Regency is 4,764,53 Ha with 56.8% is irrigated rice field and 3,610.67 Ha (43,11%) other is rainfed land. The large area of rainfed lowland rice field becomes a challenge and obstacles for the realization of food security programs. Rainfed lands are the kind of farm that completely depend on the need and availability of water to rainfall. Although it has a fairly high rainfall, but the emergence of global climate change symptoms also affect the distribution and intensity of rainwater in the Simeulue islands. Rainfall becomes unpredictable so that the rice cultivation program simultaneously becomes ineffective. Rainfed rice fields become dormant because they are not planted by farmers due to the lack of adequate irrigation water sources.

    The location selected for this study was the Situbok village of the Tepah Tengah sub District of Simeulue island. This village has a rice field with an area of 32 ha which is entirely a rain-fed rice field. Utilization of groundwater so far only to meet the needs of households. Utilization of shallow groundwater from wells by the community, lifted by a pump powered by electricity and generator, will require high operational costs (electricity or fuel) so that sustainability of the pump business in the utilization of ground water can not be maintained. One of the energy that can be used free of charge and available at any time is the source of solar energy.

4.2 Potential of solar power

Solar radiation is an important indicator for building a solar energy irrigation system because it is a source of energy driving the pump on the irrigation system. So the adequacy of solar radiation will ensure the application of solar irrigation systems. [2] determined that the sun exposure rate should be more than 30% to eligible to develop a solar powered irrigation system. Based on the measurement data as shown in table 1, the sunlight level in Situbok Village is an average of 43.75% which means that this area is feasible for the development of solar irrigation system.

Tabel 1. Solar Radiation of Situbok Village.

Day	Observation time(pm) (mv)			Solar radiation (w/m^2)
	08.00 - 09.00	12.00 - 3.00	16.00 - 17.00	
1	1	4,1	5,8	189,49
2	1,8	11,3	3,9	299,36
3	6,5	10,8	1,2	398,09
4	2,7	10,2	3,3	300,96
5	4,3	8,9	3,8	339,17
6	5,2	3,2	4,9	294,59
7	3,8	8,5	5,7	347,13
8	3,5	7,5	3,2	281,85
9	5,6	8,9	4,2	386,94
10	2,6	4,2	3,2	200,64
11	3,2	11,5	5,2	367,83
12	6,4	13,3	4,1	480,89
13	3,1	7,2	2,2	248,41
14	7,5	11,3	2,4	457,01
15	5,4	11,8	6,2	458,60
16	4,3	7,2	2,3	288,22
17	5,8	7,6	6,2	404,46
18	7,8	13,4	/5,6	550,96
19	6,7	8,7	4,7	426,75
20	3,8	11,7	7,5	426,75
21	6,5	13,8	6,7	533,44
			Total	7681,53
			average	365,79

4.3 Potential groundwater

To optimize the role of rainfed land, one potential water source is through the use of ground water. Teroritically, based on its utilization, there are two types of ground water that is shallow groundwater and deep ground water. This grouping is closely related to the use of groundwater and its infrastructure needs. For areas with potential shallow groundwater sources, the utilization will be easier because the required infrastructure is simpler, so that it can be developed by local farmers independently or if support is still at a relatively limited level. Shallow groundwater sources are commonly found in soil layers that are not very deep, making it possible to be lifted to the surface using a pump. To know the depth of shallow groundwater in Situbok Village, survey and observation of existing wells in the village both open well and well covered. The results showed that the shallow groundwater depth of Situbok village ranged from 5 to 10 meters.

Depth data collection process "groundwater" in this study using resistivity Geolistrik Wenner-Schlumberger configuration are conducted using Resistivitimeter ARES. The data were collected on 1 west-east trajectory with a path length of 460 m and a space of 20 m. Coordinate of measurement path: starting point of path S0 (0 m) N 02°25'14.2 "/ E 96°18'12.2" and end point S46 (460 m) y N 02°25'43.9 "/ E 96°18'27.1". Figure 2 shows Cross-section of resistivity below Situbok track surface of Situbok village. Based on the description of cross-sectional resistivity on the track shows that the trajectory Situbok (STB) in general obtained a low resistivity value that is 2 - 100 Ωm which is alluvium. The lower resistivity value (conductive) is generally a layer containing ground water. In the cross section of the STB trajectory, the highly conductive layer of resistivity <16 μm can be seen in the range of spacing range 240 - 360 m with a depth range of ± 45 - 94 m.
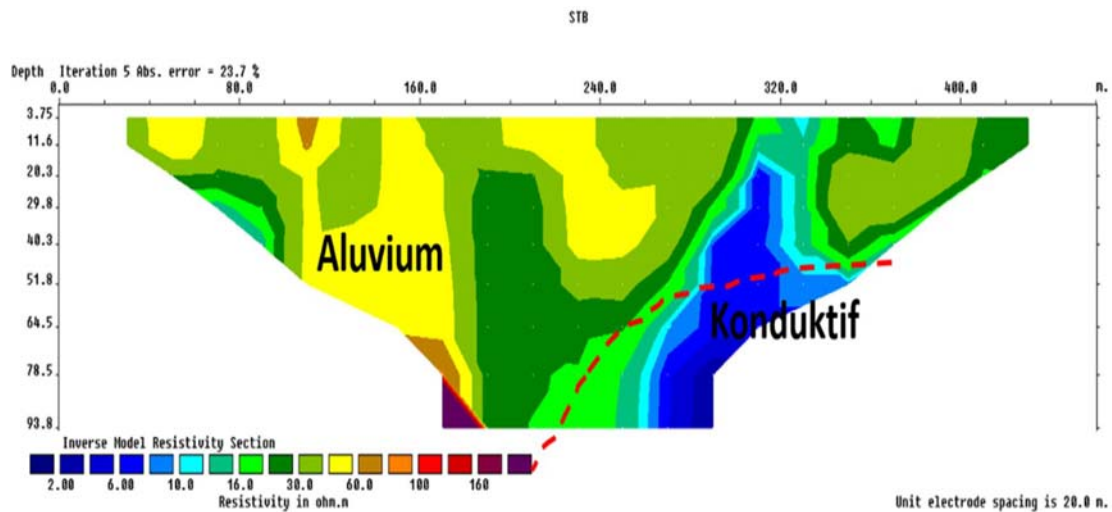
Figure 2. Cross-section of resistivity below Situbok track surface.

4.4 Land suitability

Land topography is also one of the indicators to consider in designing a solar power pump irrigation system. Optimum topography greatly determines the efficiency level of irrigation water use. If the topography is too sloping, it is estimated that the irrigation water flow range will be limited, and vice versa if it is too steep, it is estimated that there will be runoff. [2] stated the topography of land for surface irrigation 2 - 5%. Situbok land topography is 2%. It is mean that Situbok Village is suitable for developing PV pump irrigation system.

4.5 HOMER Simulation

4.5.1 Electrical load. Data Electrical loads are measured for daily hourly electrical load requirements of the pump. The main load is 2 kWh / d with a peak of 242 Wp. The hourly load consumed by the pump is presented in figure 3. The pump set requires electrical load for 9 hours (08: 00-17: 00).
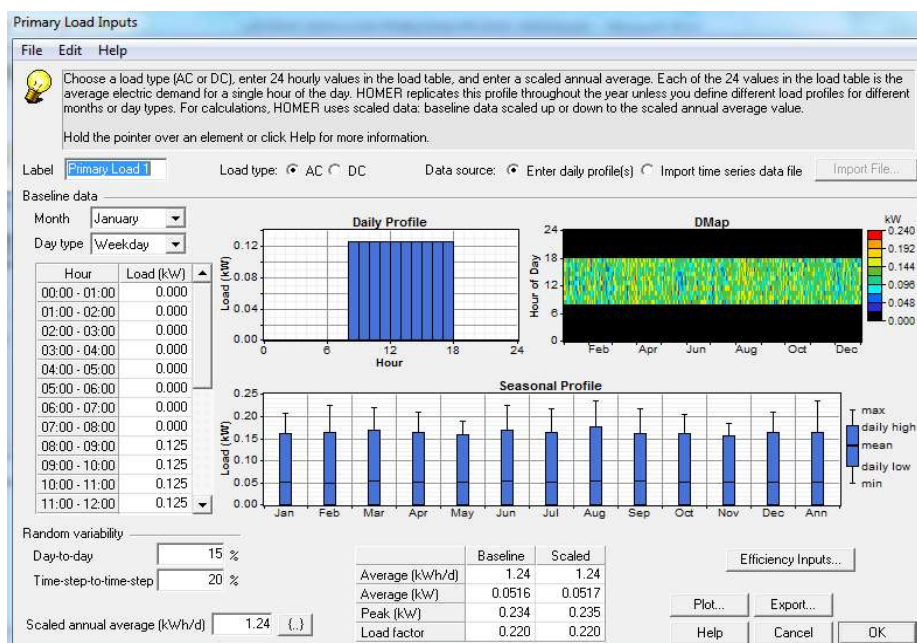
Figure 3. Electrical load.

4.6 Energy sources.

The energy source comes from photovoltaic solar panels. The total solar PV panel capacity is 0.1 kW. The initial cost of the 1kW panel is $ 89, the estimated panel replacement is $ 80. The panel's lifetime rate is 30 years. The monthly clarity index and daily radiation are shown in figure 6. Situbok location is located between latitude 2 and 5 in the north, and 96 and 7 east longitude. HOMER can help user to idendify the solar radiation from NASA satellite. Figure 4 shows the data of daily solar radiation in Stubok village.
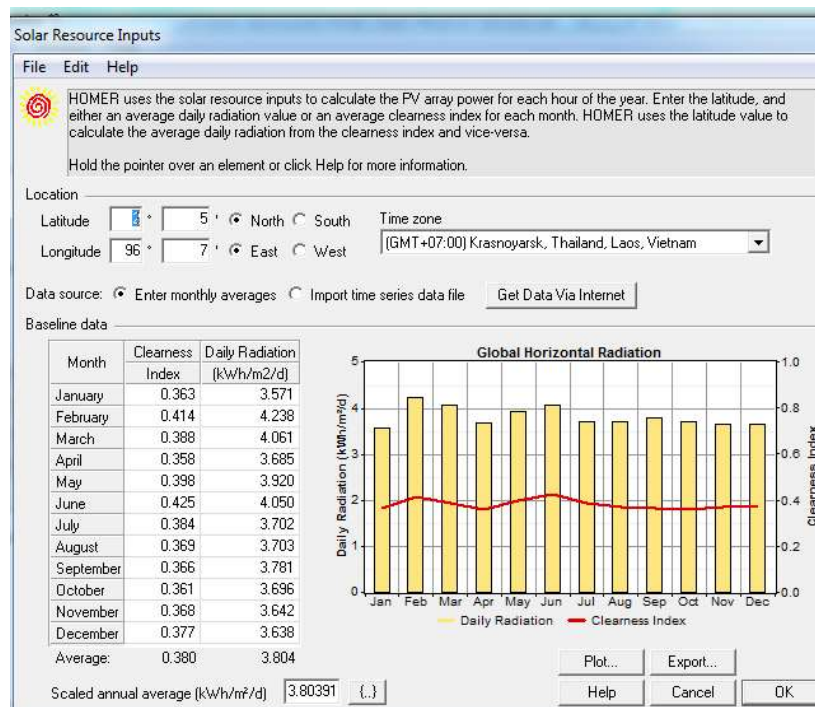
Figure 4. Daily radiation (source: NASA satellite).

4.7 System components

The battery acts as a storage of solar energy. The trojan 105 battery is considered a bank battery. Estimated cost of one battery $ 197 with $ 197 replacement. The battery requirement may contain a number of batteries of 1.2, 4.6 and 8 units.
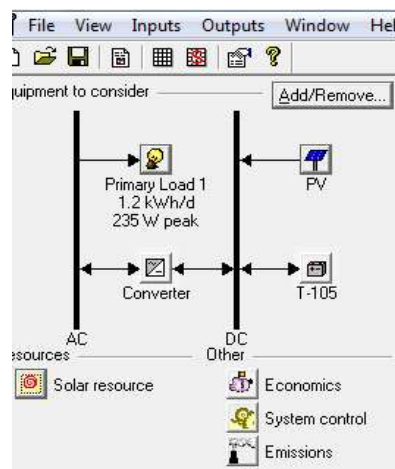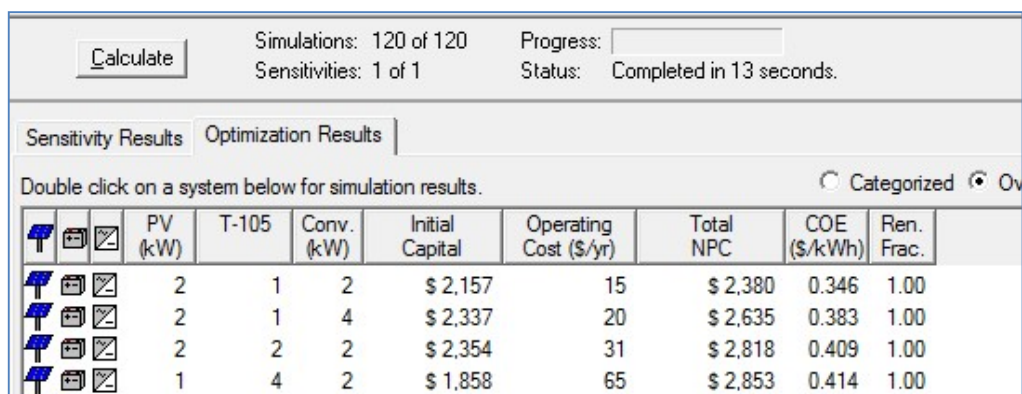
Figure 5. System components of solar power pump.

Converter is also required in this system to convert ac and dc energy. For pumping systems, installation and replacement costs are taken as $ 45 and $ 45. Various converter sizes (2, 4, 6 and 8 kW) are considered in this system. The life of the converter unit is estimated to be 15 years with 90% efficiency.

Simulation of power pump irrigation systems uses different number of components, related to energy cost and overall system performance. HOMER is used to optimize the size of components in the system, taking into account the technical characteristics of the operating system and minimizing the number of NPC systems. The optimization results for this analysis are shown in Figure 6. This system illustrates that the most optimum results obtained for this system are 2 units of solar panels, 1 battery unit and 2 converters with TNPC $ 2,380 COE 0.346 $ / kWh and operating costs $ 15 / year.

Figure 6. Optimum simulation results.

5. Conclusions

i.   Land area of Simeulue Regency is 4,764,53 Ha with 56.8% is irrigated rice field and 3,610.67 Ha (43,11%) other is rainfed lowland (suboptimal land).

ii. The location selected for this research is Situbok Village, Tepah Tengah subdistrict, of Simeulue Regency. This village has a rice field with an area of 32 ha which is entirely a (suboptimal land).

iii. Solar radiation in Situbok village is an average of 43.75% which means that this area is feasible for the development of solar irrigation system.

iv. Survey results and observations indicate that the shallow groundwater depth of Situbok Village ranges from 5 to 10 meters.

v.   Based on the measurement of deep groundwater depth in this research using Geolistrik Resistivity configuration method of Wenner-Schlumberger which is done using Resistivitimeter ARES, highly conductive layer that is resistivity value <16 Ωm with potential water lies in depth of ± 45 - 94 m.

vi. The optimization results obtained for the PV pump irrigation system in this study are 2 units of solar panel, 1 battery unit and 2 converters with TNPC $ 2,380 COE 0.346 $ / kWh and operating cost 15 $ / year.

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