Feasibility study of photovoltaic water pump for rice paddy irrigation

Ri Munarto[1a], *Arif* Faishal[2]

[1,2] Department of Electrical Engineering, Universitas of Sultan Ageng Tirtayasa, Cilegon- Banten

Abstract. Diesel pumps are commonly used for irrigation purposes of paddy fields at locations far from the grid. Diesel pumps have low reliability because they require high maintenance costs. The use of photovoltaic is a valuable option because the selection decision is not only based on direct biya modal but also includes environmental costs. These solutions reduce the impact of global warming, mitigate negative effects on air quality and contribute to sustainable economic development. Daily sun conditions in Indonesia are average in the horizontal plane within the range of 5-7 kWh/m^2/day and the average daily sun shines within the 7-9 hour. The availability of solar radiation is quite abundant and due to the high cost of grid connections, the pumping of irrigated rice paddy water is beneficial to the water needs for remote communities in Indonesia. It is known from some literature that the photovoltaic irrigation pump system is technically and economically feasible for very small systems in hectares orders. Technical and economic feasibility is determined as a function of the plant and geographical location, including climatic factors, soil quality, ground water depth and recharge rate. The objective of the research is to design a system of pumping irrigation of paddy field of photovolatics to replace previous diesel pumps that meet the criteria of feasibility standard. From simulation using PVSYST 5.0 software, it is known need of solar panel as many as 5 series module and 2 parallel module which fulfill the required eligibility criteria.

1 Introduction

Technical feasibility is determined as a function of plant type and geographical location which includes climate factor, soil quality, ground water depth and recharge rate of water. The maximum daily volumetric flow rate required for crop irrigation is determined from the maximum evatranspiration rate of the plant during its growing season [1]. Maximum evapotranspiration rate is a function of plant type, soil conditions and climatic conditions. The maximum daily flow rate required is used to determine the required pumping power. The solar panel areas needed to provide the required power use a monthly average solar insolation and are compared with the total field area [2]. Solar insolation represents the amount of solar radiation received over a single day on the Earth's surface measured in kWh/m^2/day. On cloudy days, light is scattered over sunny days, so the amount of light

[a] Corresponding author: rim.moenarto@gmail.com

reaches the surface is reduced. Areas with the same latitude that have a cloudy day, will have a very low insolation rate{1]. Solar photovoltaic water pumping has been recognized as suitable for grid-isolation rural locations in poor countries where there are hight levels of solar radiation. The power output for the photovolatic array depend upon insolator and availability of sun per daya i.e sunshine hours available on particular location per day. The insolation varies from one location to another, mounth to mounth because of seasional and climate chnge. [3]. Photovoltaic irrigation systems are technically feasible if there is enough land available to install solar panels. Technical feasibility is determined from the maximum power required for irrigation, which depends on the type of plant and geographic location.

The high cost of photovoltaic irrigation requires prior to further study, it is necessary to measure the dimensions of the photovoltaic installation as accurately as possible. The method used consists of three stages: (1) Determining irrigation needs according to soil type characteristics and climate, (2) Hydraulic analysis of pumping system made according to the aquifer depth and altitude required to stabilize pressure on the water distribution network, (3) After determines the peak photovoltaic power required for irrigation by taking into account the overall yield of the photovoltaic pump irrigation system. Use of photovoltaic irrigation pumps to increase socially significant plant output by optimizing the use of water from solar energy sources and at the same time preserving the environment. The main objective of providing a simple procedure for estimating the design requirements of a photovoltaic system to provide photographic power is based on a separate photovoltaic pumping system from the water requirements of the plant. In order for connections between irrigation systems and pumping equipment with solar energy to be energy efficient and economical, some things must be taken into account: (1) efficient use should be made to water resources, ie only the amount of water needed for crops to be raised, taking into account the rainfall prevention capacity of the soil during the rainy season, (2) the amount of water should be raised to the minimum height above the soil required to stabilize the pressure on the irrigation head and (3) the most efficient irrigation system for a particular plant that should be used.

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2 Methodology

2.1 Rainfall data

Rainfall data that have been obtained from Meteorology and Geophysics Agency Serang is the average rainfall data period of two weekly or half monthly. Then do the sorting of data from the largest value to the smallest value. From the literature, then can be obtained the amount of rainfall 80% of R80 is from the fourth order data. The amount of effective rainfall for rice plants is 70% of the rainfall of 80% R80, to obtain effective rainfall for rice crops in January the first period of 158.83, or the January rice re 10.58 mm/day, and 70% of R80 paddy in January second period was 65,87 or re of January second period that is 4,39 mm /day.

2.2. Need of water

2.2.1 The total need of water in the field

The total need of water in the field is the water required from the start of the land preparation, the land preparation, so that it is ready for planting, until the harvest time. In other words, water is needed from the beginning until the completion of planting. The total water requirement in the rice field can be calculated by the formula:

$$GFR = Etc + P + WLR \tag{1}$$

GFR : the need for total water in the rice field (mm/day) or (Liter/day hectare)
Etc : Evapotranspirasi costant (mm/day)
WLR : Water Layer Replacement (mm/day)
P : Perlocation.

2.2.2 Needs water retrieval (DR)

$$DR = \frac{NFR}{8.64 * ef} \tag{2}$$

DR : the need for water in the field (Liter/sec/hectare)
NFR : Net water need in paddy fields (mm/day)
ef : Efficieny of irrigation (65%)

2.2.3 The need for clean water in the fields (NFR)

The need for clean water in the fields is the need for total water in the fields reduced by effective rainfall.

$$NFR = Etc + P + WLR - \mathrm{Re} \tag{3}$$

Re : Effectice rainfall (mm/day)
After the net water needs are known, the water requirement for irrigation of rice crops can be obtained, so that the following values are obtained:
IR in the first January period -2.69 mm/day
DR in January the first period -0.311 liter/second/ hectare
IR in January second period 6.83 mm/day
DR in January second period 0.79 liter/second/hectare,
and then the calculation can be continued covering the next months in a year. Taking water through a photovoltaic pump to irrigate a rice plant area of 2101.44 m2 or 0.2101 hectares, then the monthly water requirement for flowing rice cultivation can be shown in Table 3.1. From table 3.1, it can be seen that the maximum water requirement for rice cultivation process is August at 31.74 m^3/day.

2.3 Batterey

The required battery capacity can be calculated at 77.90Ah / day. With a voltage rating of 48 V, it takes 4 batteries that strung the series. Design calcultation for solar pumping system[4]:

- Head of water level from the pump to the vertical lift (6.42 m)
- Pipe length 34,42 m

When installed a water storage tank with a height of 2.82 m and a diameter of 4.37 m, then can be calculated the following :

- Flow rate of 190 liters/minute
- Friction loss 1.37 m (2 inch diameter pipe)
- Total Dynamic Head 7.84 m
- Hydraulic pump energy 0.67740 kWh/day
- Hydraulic power 135.48 W (assuming 5 hours of solar irradiance)
- Mechanical power, P_m = 301.06 W
- Power, P_e = 327.24 W
- System efficiency 41.09%
- Duration of operation of pumps 2,983 hours/day (rounded 3 hours/day) .

2.4 The size of photovoltaic array

The size of photovoltaic array is determined based on the required electrical power, so that the photovoltaic area, PV area = 2,875 m^2. From the photovoltaic area, Peak Solar Insolation (100 W / m^2) and solar panel efficiency, obtained power generated by solar panels, $P_{watt\ peak}$ = 421.18 Watt peak. For a 72 V voltage rating, it takes a series of solar panel series on one string of 4.11 and rounded to 5. The number of string strings is 1.02 (rounded 2), $V_{mpp\ array}$ = 87.5 V, $I_{mpp\ array}$ 11.42 A.

2.5 Solar panels

The laying of the elevation angle of the solar panel is determined by the location of the laying area of the solar panel. Geographical location of Banjarsari village can be seen in Table 1. Due to the geographical position of the Banjarsari village area in the southern hemisphere, the solar altitude reference is based on the north pole of the earth and the tilt angle is oriented towards the North Latitude (LU).

Table 1. Geographical location of banjarsari village

	Winter solstice	Equinox	Summer solstice
Declination	+23,5 °	0	-23,5 °
Solar Altitude	107,43 °	83,93 °	60,43 °
Tilt angle	-17,43 ° LU	6,07 ° LU	29,57 ° LU

The determination of the elevation angle of the solar panel is determined based on the average tilt angle value during winter solstice and summer solstice, then the angle of elevation of Banjarsari is 23° LU. Determination of fixed tilt angle is recommended at least 15° [8]. This is because a low tilt angle can make solar panels covered with dust and stagnant water when exposed to rainfall that will result in reduced output energy. The azimuth angle of solar panel used using azimuth angle obtained from research result using solar tracker from case study of Serang area (Hardiansyah, 2012).

3 Results and discussion

Table 2 shows the balance and main results of the paddy irrigation pump rice irrigation system. The global horizontal irradiation per year is 1381 kWh/m^2. The virtual energy of photovoltaic arrays at Maximum Power Point, E_{ArrMPP} is 1139.5 kWh. The required energy operates an average annual pump of 35.36. The energy required to fill the water tank to the full averaged annual 17.43 kWh. The height of the pump head is 7.092 m. The effort required for pumping an annual average of 23.61 m^3/day. While the business is actually used for pumping 23.55 m^3/day. Miss occurs in several months of the year, ie the months of August, September, October and December amounted to 4.109 m^3/day, 2.735 m^3/day, 1.764 m^3/day and 0.445 m^3/day. Average miss 0.865 m^3/day

Table 2. Balance and Main Result

Months	**GlobEff (kWh/m^2)**	**E_{arrMPP} (kWh)**	**E_{pumpOp} (kWh)**	**E_{tkFull} (kWh)**	**H_{pump} (meter)**	**W_{pump} (m^3/day)**	**W_{used} (m^3/day)**	**W_{miss} (m^3/day)**
January	145,5	120,3	29,59	50,09	7,001	16,23	14,35	0,000
February	112,4	92,6	28,39	34,25	6,970	17,00	17,29	0,000
March	131,4	108,5	39,32	31,35	7,095	21,52	21,55	0,000
April	114,0	93,9	44,24	16,20	7,107	25,07	25,08	0,000
Mei	109,4	90,8	46,22	10,35	7,084	25,40	25,53	0,000
June	97,8	81,1	46,34	4,22	7,115	26,58	26,47	0,000
July	105,9	88,2	38,84	15,79	7,095	21,32	21,39	0,000
August	92,0	75,8	46,50	1,86	7,215	25,73	26,63	4,109
September	96,4	79,5	47,96	0	7,205	27,51	28,32	2,735
October	143,8	117,4	54,76	21,63	7,090	30,26	27,46	1,764
November	119,2	98,5	47,35	17,43	7,092	26,81	26,73	0,000
Desember	113,6	93,0	35,56	24,42	7,065	19,52	19,45	0,445
Years	1381,4	1139,5	501,17	227,59	7,107	23,61	23,55	0,865

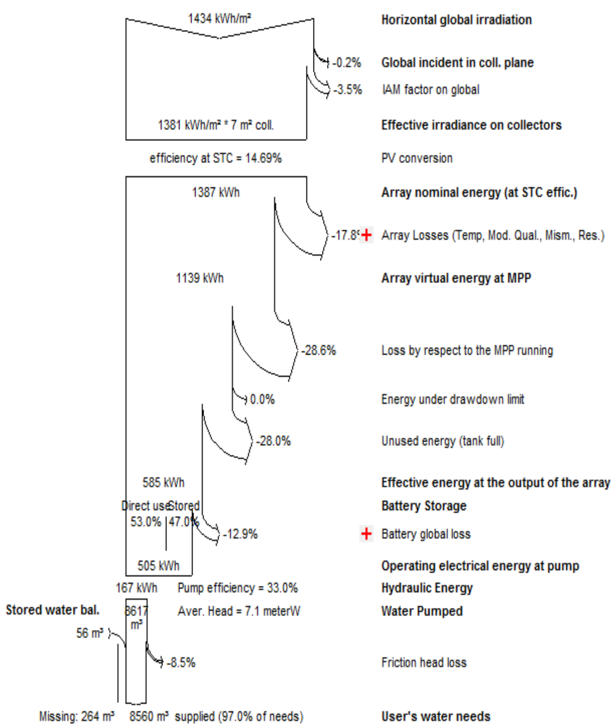

Fig. 1. Overall loss diagram

Figure 1 shows the overall system disadvantage diagram of irrigation pump irrigation system of agricultural land in Banjarsari village. Horizontal global irradiation 1434 kWh/m^2. Irradiation is effective on the collector field 1381 kWh/m^2. The magnitude of irradiation is effectively influenced by two environmental factors, namely the incident global factor of 0.2% and the Incidence Angel Modifier on global resulting in a decrease in irradiation that actually reaches the 3.5% photovoltaic cell surface associated with radiation in the normal event. Further photovoltaic cells convert solar energy into electrical energy. After photovoltaic conversion, the nominal array energy is 1387 kWh/m^2. Efficiency of photovoltaic arrays 17.8% in Standard Test Condition. Virtual energy array obtained 1139 kWh. Effective energy at 585 kWh array output. Battery efficiency 12.9%. The electrical energy used operates a 505 kWh pump. Pump efficiency 33%. Hydraulic energy 167 kWh. Water pumped 8617 m^3. Friction head loss of 8.5%. Water required user 8560 m^3. Water lost 264 m^3.

4 Conclusion

In this research, the design result of irrigation pumping system of rice field photovoltaic in Banjarsari village, Serang regency with the software used. Maximum solar irradiation at tilt angle 23^o for Banjarsari village is close to the latitude of its location (23^{o}28') and no shadding effect should be considered. In the irrigation pumping system of paddy fields of photovoltaic rice, the energy used injects pumps is 505 kWh (pump efficiency 33%). A Performance Ratio of 0.76 and some power losses can be calculated. Known miss occurs on several months of the year, with the largest miss in August of 4.109 m^3/day.

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