Solar water pump as a solution for clean water distribution in Nunleu village, Amanatun Selatan District, Timor Tengah Selatan -NTT

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Abstract. Nunleu Village is one of the villages in Timor Tengah Selatan Regency in NTT in which until now has experienced difficulties in accessing clean water. The difficulty in clean water distribution is not caused by the unavailability of water sources, but due to the Nunleu topology which consists of valleys and cliffs where the majority of the water sources are located under cliffs and valleys. This situation is exacerbated by the absence of electricity supply from PLN. This study aims to design and build a solar-powered water pump system to help Nunleu residents in the distribution of clean water. The solar pump system was built in Dusun 2 Nunleu which has a total population 150 with needs per capita per day is 40 liters. Result of the research shows that the water pump system built in Nunleu village was able to provide 6000 liters of clean water in approximately 5 hours.

Keywords: solar, pump, Nunleu

1. Introduction
Nunleu village is one of the villages in the southern amanatun sub-district, South Central Timor NTT which is still experiencing difficulties with access to clean water. The population in the village is 2400 people consisting of 1150 men and 1250 women. The main livelihood in this area is farming which is generally done by men, whereas women usually work as housewives.

The need for clean water in Nunleu becomes very vital to meet the needs of life such as, drinking, cooking, bathing, washing, sanitation, health needs, livestock needs, agricultural needs etc. Geographically, nunleu village consists of cliffs and valleys, with fairly low temperature conditions. In mid-May to August, temperatures in nunleu are able to reach 14 degrees celsius.

The cause of the clean water problem in Nunleu, is not because of the unavailability of clean water resources but because of the distance of water sources that are far and located in the valley area. Another obstacle encountered in Nunleu Village is that it does not yet have access to PLN’s (National Electrical Company) electricity so it is difficult to operate water dynamos on clean water distribution systems. To overcome this, the application of solar cells as a supply based on renewable energy can be a solution in answering the electricity needs in Nunleu Village.

As a solution to the problems described above, a solar powered water pump is proposed to
solve the problem of clean water in the village of Nunleu, South Amanatun District. This technology does not depend on PLN electricity as power supply so that it can be used in areas that have not been reached by electricity network.

The water pump system is planned to be built in Hamlet 2 with a total community of around 150 people. Water consumption per person is assumed to be 40 liters per day so that the total water that must be distributed is around 6000 liters.

2. Methods
The method used in this research consists of system design, system installation, and system performance testing. The water pump system is planned to be built in Dusun 2 Nunleu with a total community of around 150 people. Water consumption per person is assumed to be 60 liters per day so that the total water that must be distributed is around 9000 liters.

2.1 Design
2.1.1 Friction Loss on Suction Pipe
2.1.1.1 Loss on Straight Pipe

\[ hf = \frac{10.666 \cdot Q^{1.85}}{C^{1.85}D^{4.85}} \cdot x \cdot L \]

\[ hf = \frac{10.666 \cdot 0.00167 \cdot m^2}{130^{1.85} \cdot 0.032 \cdot m^{4.85}} \cdot x \cdot 1.5m \]

\[ hf = 0.254m \]

2.1.1.2 Loss on turn
Before calculating the loss on turn (hf), we need to obtain the coefficient of loss

\[ k = \left[ 0.131 + 1.847 \left( \frac{db}{2R} \right)^{3.5} \right] \frac{\theta}{90}^{0.5} \]

\[ k = \left[ 0.131 + 1.847 \left( \frac{32}{2 \pi \cdot 27} \right)^{3.5} \right] \frac{\theta}{90}^{0.5} \]

\[ k = 0.294 \]

\[ hf = k \left( \frac{v^2}{2g} \right) \]
by assuming the speed of the water is 2m/s on turn then:

\[ hf = 0.294 \cdot \frac{2^2}{2 \times 9.81} \]

\[ hf = 0.060m \]

2.1.1.3 Head Loss on Suction Strainer
Friction Loss factor (k) for suction strainer is 1.970, then

\[ hf = 0.197 \cdot \frac{2^2}{2 \times 9.81} \]

\[ hf = 0.402m \]
Hence, total of Losses on Suction Pipe is = 0.254 m + 0.060 m + 0.402 m = 0.716 m

2.1.2 Friction Loss on Discharge Pipe
2.1.2.1 Loss on Straight Pipe

\[
h_f = \frac{10.666.0.00167 \cdot m^{1.85}}{130^{1.85} \cdot 0.032 \cdot m^{4.85} \cdot x \cdot 10 \cdot m}
\]

\[
h_f = 1.695 \text{ m}
\]

2.1.2.1 Loss on turn

A head loss on 90° turn for discharge pipes is similar with a head loss on turn for suction pipes (hf = 0.060 m). There will be 4 of 90° turns connected to the discharge pipe. Hence,

\[
h_f = 3 \times 0.060 \text{ m}
\]

\[
h_f = 0.180 \text{ m}
\]

Head Loss for 45° turn is calculated as follows

\[
k = \left[0.131 + 1.847 \left(\frac{D_b}{2R}\right)^{3.5}\right] \left(\frac{\theta}{90}\right)^{0.5}
\]

\[
k = \left[0.131 + 1.847 \left(\frac{32}{2 \times 32}\right)^{3.5}\right] \left(\frac{45}{90}\right)^{0.5}
\]

\[
k = 0.246
\]

\[
h_f = k \left(\frac{v^2}{2g}\right)
\]

\[
h_f = 0.246 \left(\frac{2^2}{2 \times 9.81}\right)
\]

\[
h_f = 0.050 \text{ m}
\]

For 2 of 45° turns connected to the discharge pipe,

\[
h_f = 2 \times 0.05 \text{ m}
\]

\[
h_f = 0.100 \text{ m}
\]

Hence total of Losses on Discharge Pipe is = 1.695 m + 0.180 m + 0.100 m = 1.975 m

Total head loss for Suction and Discharge Pipes = 0.716 m + 1.975 m = 2.691 m

Total Head Pump (H) is the total distance (height) from end of suction pipe to the end of discharge pipe plus all the total head loss on pipe and loss of the flow = 6 m + 2.691 m + (22)/(2 \times 9.81) = 8.794 m

Hidrolic Power (Ph)

\[
Ph = \rho \omega gHQ
\]

\[
Ph = 1000 \text{ kg/m}^3 \cdot 9.81 \text{ ms}^{-2} \cdot 8.794 \text{ m} \cdot 0.00167 \text{ m}^3/s
\]

\[
Ph = 144.06 \text{ Watt}
\]
Shaft Power (Psh)

\[ ns = 1460 \times \frac{\sqrt{0.1 \ m^3/min}}{8.794^{0.75}} \]

\[ ns = 90.412 \]

According to graphic below, the efficiency (\( \eta_p \)) for \( ns = 8.794 \) is 98% . Hence, using

\[ Psh = \frac{P_h}{\eta_p} \]

\[ Psh = \frac{144.06 \text{ Watt}}{0.98} \]

\[ Psh = 147 \text{ Watt} \]

Power Input

\[ P_{in} = 1.3 \times Psh \]

\[ P_{in} = 1.3 \times 147 \]

\[ P_{in} = 192 \text{ Watt}. \]

Motor rated power used is 250 Watt.

2.1.2.2 Numbers of Battery

The pump is able to deliver the clean water up to 32 liters/min, hence for 5200 Liters, duration is 281.25 minute or equal to 4.69 hours of operation per day. For a day, the number of energy needed to operate the pump:

\[ E = 250 \text{ W} \times 4.69 \text{ h} \]

\[ E = 1170 \text{ Wh}. \]

A 100 Amps, 12 V of DC battery can provide 1200 Wh. Hence, numbers of Battery = 1170/1200 = 0.97 = 1 battery

2.1.2.3 Numbers of Panels

The duration of radiation is 5 hours. Hence, for 1170 Wh, the average power is

\[ = 1.3 \times 1170 / 5 \]

\[ = 304.2 \text{ Watt} \]

Using 170 Wp of Solar Panel, the number of panels needed = 304.2 /170

\[ = 1.79 \text{ panels} \]

\[ = 2 \text{ Panels (340 Watt)} \]

Solar Charge Controller

\[ = 340 \text{ Watt/ 12 = 28.3 A} \]

Size of Inverter

Assuming the inverter efficiency is 50%, inverter capacity is = 1.3* 250/50% = 650 Watt. The capacity of the inverter used is 1000 Watt.
2.2 System Installation

Figure 1. Solar Pump System

Figure 2. Solar Pump System Installation

3. Result and Discussion

The system is able to deliver clean water from the source to the water container near residents with debit around 28 Litre/ min. It means the system will take around 5.3 hours to provide 9000 litres clean water for the residents.

| Time (h) | Voltage (v) | Current (Ampere) |
|----------|-------------|------------------|
|          | DC Battery  | AC Inverter      |                  |
| 1        | 13          | 210              | 1.8              |
| 2        | 12.2        | 225              | 2.1              |
| 3        | 12          | 220              | 1.9              |
| 4        | 12          | 220              | 2                |
| 5        | 12          | 220              | 2                |
| 6        | 12          | 220              | 2                |
4. Conclusion
In order to provide an access to clean water, a solar-powered water pump system was built in Dusun 2 Nunleu. The system should be able to provide about 6000 liters of water for 150 villagers. The solar pump system built consists of two 170 wp solar panels, 100 Ah battery, 12 V, 1000 watt inverter and a 250 Watt water pump with duration of operation around 5 hours. After installation, the system is able to deliver clean water about 28 liters per minute of. Hence for 5.3 hours the target to provide 6000 liters of clean water can be met.

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