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Solar Energy for Water Optimization: Advancing Clean Water Distribution at Universitas Samudra

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Abstract. The use of solar energy has become increasingly popular in recent years due to sustainability and environmental benefits. Universitas Samudra is designing the centralization of water distribution using solar energy as an energy resource. By using solar energy, universities can reduce their carbon footprint and energy costs while improving access to clean water for students, staff, and the surrounding community. This paper explores the benefits, challenges, design, and optimization of solar energy in pure water distribution, focusing on the technical and optimization of implementing such systems. The optimization is based on the water demand analysis and water source regarding the rainwater harvesting, then distribution points, including time patterns, peak demands, and seasonal fluctuation. The analyzing variables include the flow and residual head at each point distribution, pressure drop, pipe sizing, storage tank sizing, and water supply capacity input to each storage tank. The data is also based on the university's master plan and blueprint for the next 30 years of Development. Furthermore, the data will be analyzed and calculated to obtain optimum distribution pump capacity and pump working hours. The system was Analysed and calculated using Epanet hydraulic modeling software. The calculations result are that the distribution pump capacity is 16 L/s, the head is 30 M, the works for five hours a day, the power is 4.7 kW, the total energy is around 23.5 kWh per day, and The solar panel is eight kWp.

Keyword:

Solar Energy, Energy Cost, Environmental, Optimizing.

1. Introduction

Water and Energy demands are increasing due to the increase in the population [1]. Development, economic and human survival have the intertwining of each other [2]. In a university, clean water is a basic need for the student. Water is essential for any community, including a university, to function correctly. Water infrastructure must comply with the requirement, and it is used for drinking, sanitation, cleaning, and other purposes. Therefore, it is crucial to have a well-designed and well-maintained water system in a university to meet the campus community's needs.

The water system in a university should be able to provide clean and safe drinking water to all students, staff, and faculty. The system should also handle the water demand of the entire campus, including academic buildings, residence halls, and recreational facilities. The water system in a university should be designed and maintained with the health and safety of the campus community in mind.

The clean water system, including the reservoir, storage tank, supply system, water treatment, and distribution system, require energy [3, 4]. In global urban areas, water transportation and water treatment are among the enormous energy consumption and CO_2 emission sectors [5]. Energy and water have a substantial nexus [6].

Renewable energy must be considered for applicating in all aspects of energy consumption. Solar energy has become one of Indonesia's priority renewable energy resources because it is abundant and can be accessed everywhere [7]. Conventional energy is not environmentally friendly [8]. Using solar energy for electrical installations can significantly reduce the carbon footprint that can cause the greenhouse effect, air pollution, and health impacts and minimize effective costs [9, 10].

Solar energy can be used in the water distribution system [11], especially for powering the transfer pump. However, solar energy only exists during the daytime. Therefore, the clean water operational time must be synchronized with the solar exist, and it will affect the time pattern of the water supply.

Shepovalov et al. [12] show a clean water pumping system using solar energy that can handle the distribution of water in rural with a high intensity of sunlight. Meanwhile, Candra et al., using maximum power point tracking, have produced adequate energy for a clean water distribution system [13]. A solar-powered water pump system is more economical and environmentally friendly than diesel or wind power [14].

Despite Indonesia having a considerably high intensity of solar energy, around 4.8 kWh/ m^2/day [15], the utilization of solar power for powering transfer pumps has yet to be initiated widely. This paper aims to optimize the water distribution system by utilizing solar power for power transfer pumps.

Figure 1 is the Universitas Samudra Master Plan, including the Social facilities and recreation area. Each building must be supplied with clean water in sufficient quantity and pressure—the prediction of the total population community base on each building area.

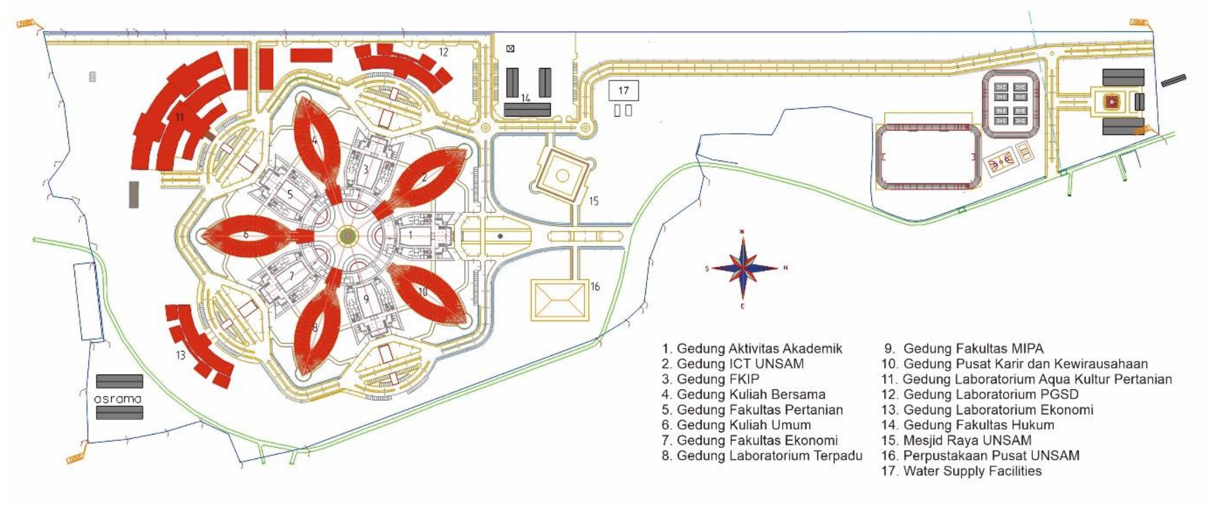

Figure 1. Universitas Samudra Master Plan.

2. Theoretical Approach/Methodology/Scenario

Universitas Samudra is one of the state universities in Aceh Province, Indonesia. A water distribution system was designed to serve clean water for every building with adequate pressure and quantity for every person. The design is based on the university's master plan and blueprint for the next 30 years of development. The water resources come from rain harvesting, deep well boreholes, and municipal water corporation.

The methodology approach is based on the Universitas Samudra master plan and the water base demand at each building. The base demand was calculated due to the number of staff, students, and community who stay at each building and how many hours they stay within a day. The total amount of water needed at every building was modeled and simulated using EPANET software to get the optimization design of the water flow, pipe sizing, and storage tank sizing. The clean water base demand per population refers to Indonesian Nasional Standard (SNI) 03-7065-2005 [15, 16], which is 26.6 liters/person.

The water supply system is centralized. Furthermore, the transfer pump is centralized at a location and will distribute the clean water to every place and building that has installed the storage tank. The water sources from rain harvesting, deep well boreholes, and Municipal Water Corporation are collected in a reservoir and then transferred to the water storage tank at each building. The reservoir capacity was calculated based on the total demand of clean water consumption, Water resources supply, and supply time pattern. The storage tank capacities at each building are calculated according to the flow inlet and outlet of the storage tank, base demand at the tapping, and consumption time pattern. The system at the building works gravitationally due to the storage tank's position at the top of the building. The storage tank elevation varies according to the land contour and the height of the buildings.

Pipe sizing in the building was designed and constructed by the contractor. The piping network from the clean water supply pump and every building was designed, and figured the sizing because it can affect the total energy of the transfer pump due to the hydraulic power dan head loss. The transfer pump capacity was estimated by accumulating the water demand from all buildings. The pump's total head was simulated using the software of Epanet 2.0. The total head influences the hydraulic power and amount of water pumping to the designated points. A lower head affects the residual pressure and lack of water quantity, and a higher head will consume more power and make the pump run inefficiently.

The total head was simulated to ensure the hydraulic and certain water quantity was adequate. The PVC and galvanized pipe were applied to the design, and the size is very according to the pipe position. The pipe size is varied from 1" to 8" and follows the code of SNI 06-0084-2002. The pipe length follows the land contour and lies on the roadside. The total head is varied in the simulation from 10, 20, and 30 M.

The transfer pump consumes the most significant energy. The amount of power depends on the water's quantity and the pump's total head. Water quantity is calculated based on water demand at every tapping point. The total head obtained from the total head loss of the system and residual head at each taping point. The lowest energy consumption by the system measures maximum efficiency. The lowest energy consumption can be obtained by implementing the proper design.

The energy the pump needs is influenced by system design, such as piping sizing, tank sizing, pressure drop, reservoir, time pattern, and water supply capacity to each storage tank. The optimum design can be obtained by calculating all of the component designs. It must be conducted to get the proper size for every part of equipment in the system and to bring the optimum balance between investment, maintenance, and operation cost.

Figure 2 shows the piping network distribution line, the network as modeling to do simulation. The storage tank was placed at each building at the highest elevation, and the tank high is 2.5 m.

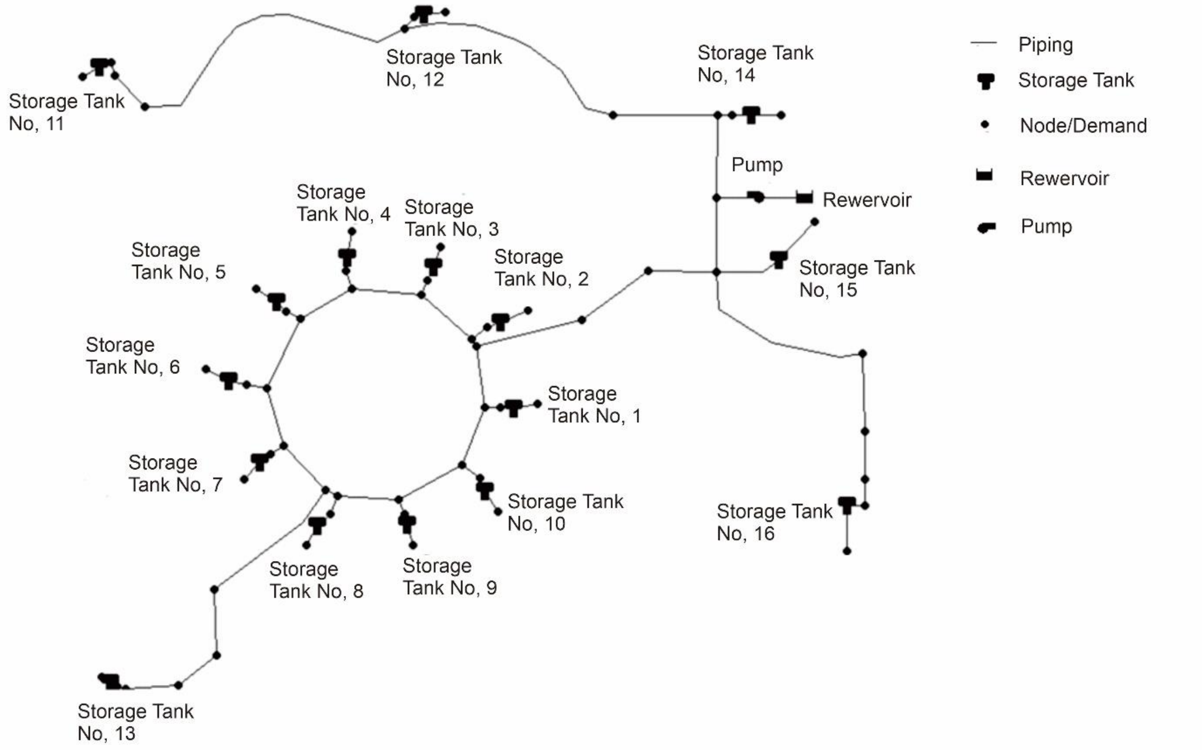

Figure 2. Distribution line piping network

The pump's power consumption can be calculated by multiplying some variables, particularly the total head and debit of water. This power consumption will be served by solar energy during daytime and sunlight exist. As an assumption, the pump running time is five hours daily during solar existence. Photovoltaic (P.V.) devices will be installed to produce electricity to power the pump. The electricity will transfer directly to the pump by off-grid connection with the state electricity company (PLN). The backup power will be provided to keep the system active when the P.V. does not produce electricity during the rainy season.

3. Results/Discussions/Implementation

Table 1 shows the data building area, number of consumers, total clean water demand, and storage tank capacity. The reservoir capacity was obtained at 181.7 M^3 and rounded to 185 M^3. The total demand is rounded to 292 M^3/day with five hours daily working, and the pump capacity is 16.2 liters/second.

Table 1. The title or short description of the tables

Building No	Floor Area (M^2)	Number of Consumers	Total Demand M^3/Day	Storage Tank Capacity (M^3)	Flow Inlet L/s
1	1,395	260	6.747	4.100	0,375
2	5,100	950	24.665	15.000	1,370
3	1,395	250	6.747	4.100	0,375
4	5,100	930	24.665	15.000	1,370
5	1.395	250	6.747	4.100	0,375
6	5,100	930	24.665	15.000	1,370
7	1,395	250	6.747	4.100	0,375
8	5,100	950	24.665	15.000	1,370
9	1,395	250	6.747	4.100	0,375
10	5,100	930	24.665	15.000	1,370
11	13,150	2.400	63.598	38.500	3,533
12	4,292	780	20.755	12.500	1,153
13	3,665	670	17.723	10.500	0,985
14	2,890	525	13.972	8.500	0,776
15	750	135	3.627	1.100	0,202
16	3,140	570	15.177	9.500	0,843
	60,360	11,030	291.912	184.600	16,217

3.1. Pump Total Head and hydraulic power.

The total head was simulated using Epanet 2.0. Every designated point was investigated to be verified whether the water capacity was sufficient to reach all points. Two sample storage tanks will be investigated, the farthest ones (Tank no. 13), and such points will be compared to the nearest ones (tank no. 15). Figure 3 shows the elevation change according to time, in which the total head has given 10 m. The initial elevation of the storage tank is 15.5 m, assuming that the tank's high is 2.5 m. After 30 hours, the elevation decreases to 13 m, and the storage tank is empty, which means there is no water flow to the storage tank.

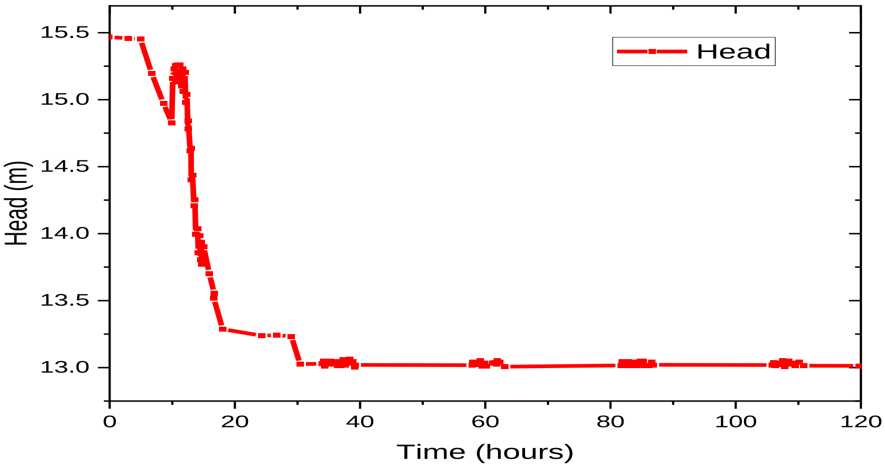

Figure 3. Storage Tank elevation change at 10 m head pump (tank no 15).

Figure 4 is indicated that the additional head of 20 m gives hydraulic power to reach storage tank no. 15, which can be seen in the tank's lower level no exit 14.7 m, which means there is water flow to the storage tank and minimum level of tank 1.7 m. Figure 5 shows water elevation changes at storage tank no. 13, which is the farthest, where the water elevation is down to the lowest level. That indicates the hydraulic power is insufficient to convey the water to the storage, so the tank empties at 105 hours. The high elevation caused it due to the more extensive head loss and hydraulic power needed to reach the point.

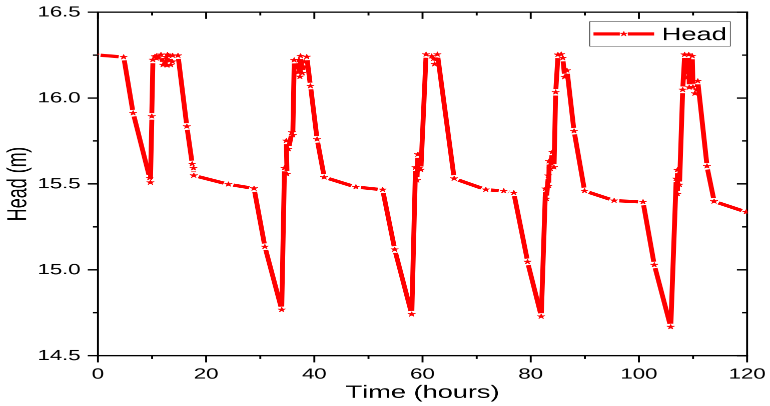

Figure 4. Storage Tank elevation change at 20 m head pump (tank no 15)

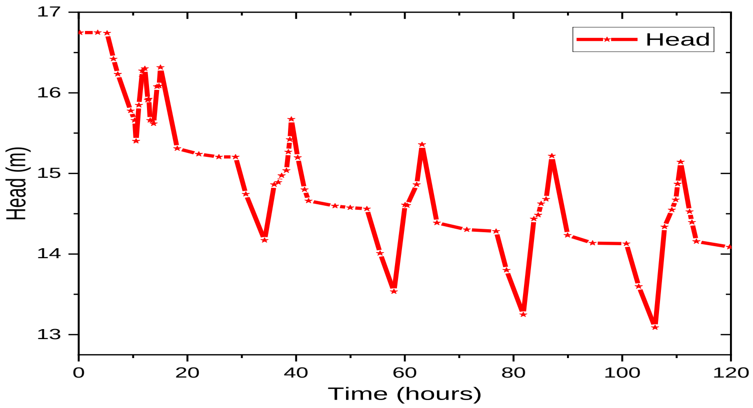

Figure 5. Storage Tank elevation change at 20 m head pump (tank no 13)

As shown in Figure 6, the water level is stable, not exiting the minimum limits (13 m). It can happen because the hydraulic power is sufficient to flow water to the farthest tank. The Head pump of 30 M is the minimum head that can be applied to the pump. The lower head will prevent the flow from reaching the farthest point.

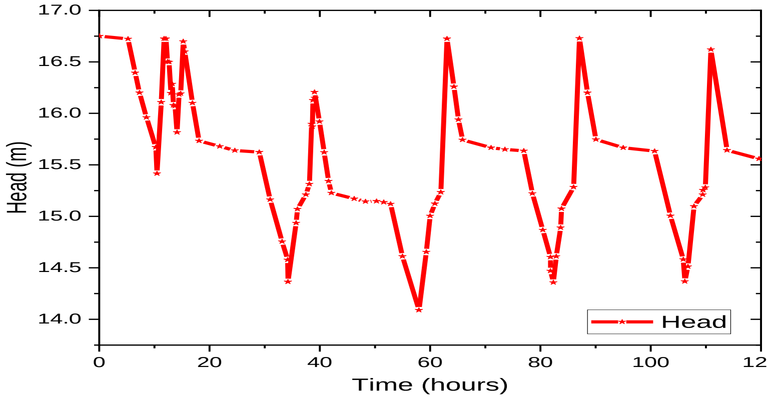

Figure 6. Storage Tank elevation change at 30 m head pump (tank no 13).

3.2. Pump power

The debit of the pump is 16.2 liter/second, total head 30 m, then as an assumption, the pump efficiency is 95%, then the pump power can be calculated, and the result is 4.7 kW, and if the pump running 5 hours a day, total power is around 23.5 kWh.

3.3. Photovoltaic Modules electric production system

The high intensity of solar energy, around 4.8 kWh/m^2/day [17], makes it possible to provide electricity for powering the pump. The total power needed is 23.5 kWh a day. The total solar panel needed is eight kWp, assuming the average solar energy gained is three hours. If the solar panel has 400 Wp per panel, the total panel needed is 20 Panels.

4. Conclusions/Summary/Future Perspectives

The clean water distribution system at Universitas Samudra has been designed using solar power as an energy resource. The pump capacity is 16.2 liter/second, total head of 30 m. The daily total power is 23.5 kWh, and it needs a solar panel of eight kWp. The design was optimized due to the minimum power needed to drive the transfer pump.

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