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Development of Interisland Freshwater Supply System with Micro Hydropower System

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Abstract The supply of freshwater must be conducted with considerable technical considerations based on community socioeconomic conditions. Thus, the supply of freshwater does not make the community oppose the operation and maintenance. Limbo Island is one of the islands that do not have freshwater potential; hence, people have to fetch water from Taliabu Island, which is about 3 nautical miles away. For this reason, providing freshwater with environmentally friendly technology is necessary. Given technical and operational considerations, the drinking water supply in Limbo Island comprises a system of underwater pipelines with electrical technologies and energy sources that are environmentally friendly and have low operational costs. The system does not require an operator with expertise or special education, such that it can be operated by locals. The supply of freshwater for Limbo Island is constructed with an underwater piping system with a capacity of 30 L/s to serve some of the people of Taliabu and Limbo Islands. The pipe used for crossing the sea is high density polyethylene (HDPE) pipe with a diameter of 110 mm and a nominal pressure specification of 20 bar; it has a thickness of 12 mm, with two pipes with a length of 5,800 m at the bottom of the sea. The flow system in the transmission and distribution pipe is run by gravity; thus, it does not require electrical energy. Electrical energy requirements are used for water treatment processes, such as for drive dozing pumps, mixers, compressors for pneumatic systems, lighting and other electrical needs. These requirements are met by the water energy that is processed through a micro hydropower of 12.5 kW. Micro hydropower strongly supports the operation of the water treatment plan, especially for those whose location is far from access to electrical energy by the electricity company, so that the water treatment plant operations can be carried out continuously and the operating costs are cheaper.

Keywords Micro Hydropower, Freshwater, Water Treatment, Electrical Energy, Underwater Pipeline

1. Introduction

The provision of drinking water must consider various aspects, including technology, energy use and operational and maintenance costs [1-3]. The use of technology and energy must be adjusted to the potential of human resources, supporting facilities, such as energy, and the capacity of the community, such that the constructed water supply system can function properly. The use of high technology with high energy consumption will result in expensive water prices, which is suitable for high-income people who are mostly in urban areas [4,5]. However, areas where people's income is still low need the application of technology and energy sources whose water production costs are affordable for the community.

In regions in Indonesia, such as North Maluku, a few uninhabited islands, such as Limbo, Maitara, Hiri, Kayoa and Gala Islands, have no source of clean or drinking water; thus, the water supply in these regions needs technology that can serve the needs of the community continuously, in terms of capacity and quality at an affordable price [6,7]. In meeting water needs, including washing and bathing, people have to go to the nearest island by crossing the sea, which is extremely difficult if the sea weather is not good. The community will be helped slightly during the rainy season because they can use rainwater to meet their freshwater needs [8-10].

Drinking water in areas such as Limbo Island must be provided by selecting the right technology and in accordance with regional conditions, such that the water supply system can function properly. The choice of expensive and sophisticated technology will result in high investment, operational and maintenance costs, thereby making the water production costs high. This condition will considerably affect water services to the community if implemented on Limbo Island, because water services to rural communities with small incomes cannot always be performed for business purposes. Thus, technology and energy with low operational and maintenance costs are needed. In addition, energy availability, especially in remote areas, is also limited [11-13]. Limbo Island is a small island that is about 3 nautical miles from Taliabu Island, North Maluku, Indonesia; it does not have the potential for sufficient freshwater to meet the needs of the community, so people have to fetch water from Beringin river, Taliabu Island by boat [14]. This condition makes the price of water on this island expensive due to the need for fuel costs and risks when the sea weather is not good. Hence, providing drinking water that is cheap and easily accessible is necessary. From the conditions mentioned above, technology with environmentally friendly energy must be utilised to ensure the continuity of drinking water services on these islands. The technology must prioritise systems based on gravity in terms of transmission and distribution, including the provision of electrical energy for the water treatment process [15-17]. One of the technologies applied in the freshwater supply in islands that do not have freshwater is by means of underwater pipeline. Such application is conducted based on technical studies. Figure 1 shows people on Limbo Island taking water, bathing and washing clothes in the Beringin river Taliabu Island. they come to this island regularly every 2-3 days by boat.

2. Technology of Freshwater Supply

Water on Limbo Island is provided using submarine pipeline technology with water from the Beringin River. The intake building is at an elevation of 132 m on the sea level, the water treatment plant has a capacity of 30 L/s at an elevation of 58 m on the sea level and the Taliabu Island reservoir has a capacity of 500 m^3 at an elevation of 51 m on the sea level. From this water treatment installation, two pipelines are divided: one pipe to the community housing on Taliabu Island (Salati, One Way and Nggele Villages), and the other pipe goes to Beringin Jaya Village and continues to Limbo Island by sea in the Limbo Strait with a depth of between 0 m and 47 m. Limbo Island, a reservoir with a capacity of 150 m^3 is constructed at an elevation of 19 m on the sea level to serve residential houses at an elevation between 1 m and 6 m on the sea level, with a pipe length of approximately 2 km. With this system, all of the transmission and distribution pipelines can be streamed by the gravity system. The electrical energy in water treatment plants is supplied by micro hydropower that utilises the remaining water pressure from the intake to the water treatment plant (WTP), that is, an high density polyethylene (HDPE) pipe with a diameter of 250 mm length of 1,800 m and height difference of 74 m As shown in Figure 2, the schematic of the underwater drinking water pipe from Taliabu Island to Limbo Island.

The water supply utilises environmentally friendly technology, which is classified as green technology; such technology is used in the water flow system in the transmission and distribution pipes, all of which are gravity and do not use fossil fuels as an energy source [18-20]. In the water treatment plant, conventional WTP is used, which operates with the flowing fluid and also does not require electrical energy to pump water.

Figure 1. People of Limbo Island washing clothes, bathing and taking water from Beringin River on Taliabu Island

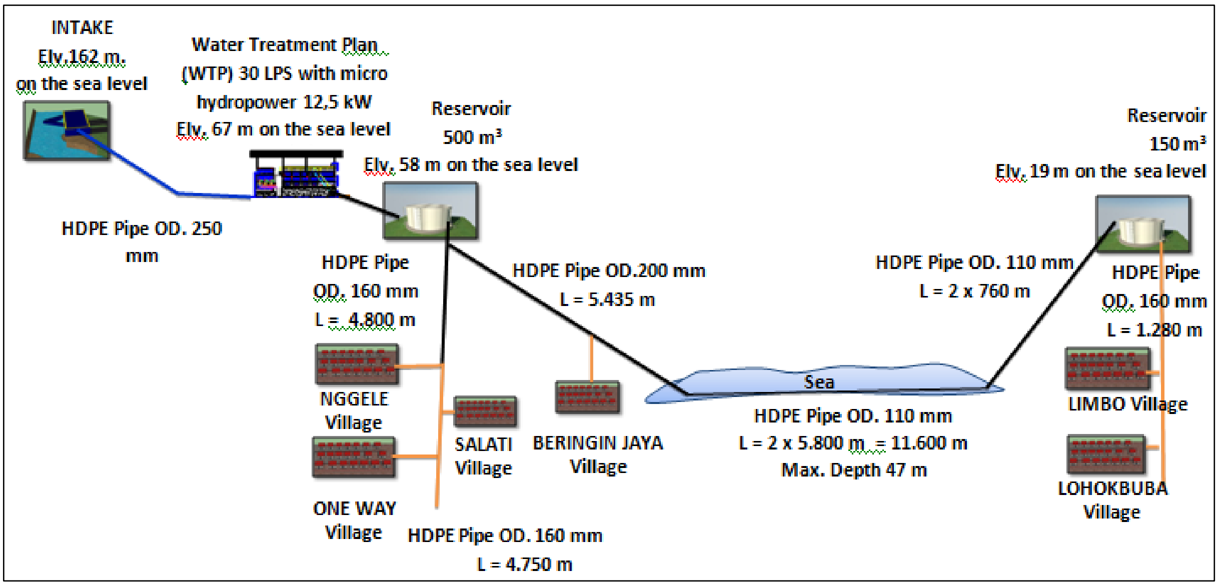

Figure 2. Schematic of underwater pipeline from Taliabu Island to Limbo Island

Table 1. Material properties of HDPE pipe

No	Property	Value	Units
1	Density	959	kg/m^3
2	Modulus of elasticity	1250	MPa (N/mm^2)
3	Modulus of sliding	481	MPa (N/mm^2)
4	Diameter of outside	110	mm
5	Diameter of inside	86	mm
6	The wall thickness of the pipe	12	mm
7	Standard Dimension Ratio (SDR)	11	
8	Tensile strength at yield	26	MPa (N/mm^2)
9	Tensile strength at break	35	MPa (N/mm^2)
10	Maximum pressure from inside	2,0	MPa (N/mm^2)

3. Dimensions and Specifications of Pipes

Calculating the dimensions of the pipe start from analysis the population in the projection year at least 20 years from now and the water needs of 0.15 m^3/person/day. The pipe dimensions are calculated as follows:

$$ID = \sqrt{\left[\left(\frac{\sum p \times W_d \times 4}{86400}\right) \times 3.14\right]}$$

where ID is the pipe diameter (mm), $\sum_p$ is the total population in the projection year (person) and W_d is the water needs (m^3/person/day). Then,

$$ID = \sqrt{\left[\left(\frac{3946 \times 0.15 \times 4}{86400} \times 3.14\right)\right]} = 0.086\, m = 86\, mm$$

With a sea depth of 47 m and a reservoir height at the location of the water treatment plant at 51 m above sea level, the water level difference in the deepest pipe is 98 m. To WTP the water hummer that can occur when the water stops flowing suddenly, which can cause a pressure twice the normal pressure of water in the pipe, a pipe with a nominal pressure of 20 bar is selected. Table 1 presents the detailed the specifications of the selected pipe.

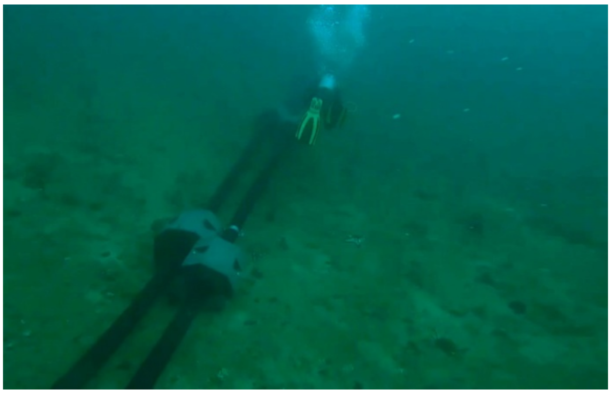

Figure 3. Freshwater pipeline on the seabed of Limbo Strait

The specifications of the HDPE pipeline will be referenced in the technical analysis of subsea pipelines. The HDPE pipe is selected for its several advantages [21-24]: (i) it does not corrode, so it lasts long in water; (ii) it has good elasticity, such that it can lie following the contours of the seabed; (iii) it is easy to maintain in case of break or buckling; (iv) its light weight makes it easy to transport and install; (v) its connection process is easy and possible to do with vessels of 5–20 GT size; and (vi) its price is cheaper than steel pipe.

The disadvantage of the HDPE pipe is that its density is smaller than sea water; thus, it takes a larger additional period to submerge than steel pipes. The pipe is installed lying on the seabed, such that it is more stable, and over time, it will be buried in sand [25-27]. The ballast concrete will also be overgrown with coral reefs; thus, it can become a new home for marine animals [28-31]. Figure 3 shows adjacent pipes installed for easy maintenance and leak detection.

4. Provision of Energy

Electrical energy is needed in water treatment plants for the drive mixers, dozing pumps, compressors for pneumatic systems, lighting and energy needs for operators [32,33]. The energy required in water treatment plants is between 7 kW and 10 kW, which can be provided by utilising water energy on the ends of the transmission pipe. The potential energy in a water treatment plant is calculated as follows:

$$P = Q.H.g.\eta_{mh} \text{ (kW)}$$

Where P is the micro hydro output power (kW), Q is the capacity of water entering the turbine (m^3/s), H is the head (difference in height minus losses − losses), g is the acceleration due to gravity (9.81 m/s^2) and η_{mh} is the efficiency of the total micro hydropower (0.65; calculated based on eff. turbine, eff. axis and eff. generator).

The intake building is at an elevation of 132 m. on the sea level altitude at V note WTP 58 m. on the sea level, a distance of 1,800 m and an estimated head loss of 8 m. The remaining head is calculated as follows:

$$H = 132 \text{ m} - (58 + 8 \text{ m}) = 66 \text{ m};$$

and if the discharge/intake water capacity is 30 L/s = 0.03 m^3/s, then,

$$P = 0.03 \times 66 \times 9.81 \times 0.65 = 12.6 \text{ kW}$$

The calculation results show that the installation of micro-hydro at the transmission pipe unit by utilizing water energy before entering the water treatment plant can meet the WTP's electrical energy needs which consist of a chemical system (compressors for pneumatic systems, lighting and other electrical needs). With the installation of micro-hydro, the energy used in this system is environmentally friendly (green energy). In this development, a micro-hydro power plant of 12.5 kW is sufficient for electricity needs at the water treatment plant, so that it can be used for lighting around buildings and access roads. The installed micro hydropower is shown in Figure 4. The micro hydro is installed at the bottom by utilizing the water pressure from the intake before entering the WTP. The micro hydro position does not interfere with the WTP work system, in fact it is very supportive in providing cheap and environmentally friendly electrical energy sources, so this technology is very effective to apply.

Figure 4. Micro-hydro installed in water treatment plants

Figure 5. People rushing to collect water at the end of an overflow reservoir pipe

5. Water Distribution

Water is distributed through pipes directly to people's homes and for public services, namely schools, ports, sports fields and places where there are many people's activities [34-36]. With the availability of fresh water in their home environment, the community is very enthusiastic because they no longer need to take water from big islands by boat which requires fuel and risks life safety, especially in the wind and wave season. In Figure 5 it can be seen the excitement of the community when taking water alternately in the over flow pipe section. The fresh water distribution system on Limbo Island is also gravitational so that there is no electricity cost for the pump, this really helps the community in minimizing the operational and maintenance costs of distribution pipes [37-39]. The position of the reservoir which has a capacity of 150 m3 and is located at an altitude of 19 meters above sea level is also sufficient to provide water pressure for the distribution process by gravity. The water pressure in the farthest pipe is more than 0.5 bar.

6. Conclusions

The selection of inter-island subsea pipeline technology for the supply of fresh water on the island of Limbo was carried out with various considerations, which prioritized operational costs, availability of technology, energy and professional operators at the construction site. The type of pipe used is HDPE pipe with a diameter of 110 mm and a nominal pressure of 20 bar whose specifications are selected based on the calculation of fresh water requirements, hydraulic calculations and the strength of the pipe to withstand various forces and environments on the seabed. This type of pipe is also safer from corrosion so it does not require special treatment. The distribution of fresh water using underwater technology from Taliabu Island to Limbo Island is carried out by gravity so that in this design there is no electricity cost for the water pump. This technology system is also equipped with conventional technology water treatment plants, all of which operate by gravity or without a pump. The electricity requirement for water treatment plants (WTP) is only for chemical systems and lighting provided by installing a micro-hydro with a power of 12.5 kW. The energy produced by micro hydro is obtained from water energy in the transmission pipe which is installed before the water enters the WTP with a capacity of 30 lps. With this system, the community can obtain good quality fresh water at affordable production costs. This technology can really benefit the people on Taliabu Island and Limbo Island. This technology can also be applied in other areas that have the same potential, so that it can help provide fresh water on islands that do not have fresh water potential.

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