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Hydropower Potential of Agricultural Dam in Bukit Merah

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Abstract: Malaysia, although having a good number of small to medium hydro power potential sites, has still not exploited all of them. The focus of this manuscript is a feasibility study of the technical viability of power generation from a medium hydropower potential site, the Bukit Merah Dam site, on the Terusan Besar irrigation canal in northern region of Malaysia. This study is carried out using flow data of 2016 from the main irrigation canal of Bukit Merah dam. The data was obtained from Department of Irrigation and Drainage, Perak. The power capacity, yearly energy output of the potential hydro site are studied in this work. Technical analysis of the power output capacity and yearly energy output of three (3) hydro-turbine types (Kaplan, Propeller, and Francis) operable at the same given head and design flow were studied. The study shows that there is a potential capacity of 2.2 MW and an annual energy generation capacity of 7028.47 MWh at a turbine peak efficiency of 92.8% at a design flow of 19.23 m3/s using Kaplan turbine.

Keywords: Agricultural Dam, Hydropower and Potential sides

I. INTRODUCTION

The energy demand of Malaysia has been steadily increasing from year to year. To meet this demand, more fossil fuel power plant has been committed to be built and will operational in the near future, despite its government having set a target for energy generation from renewable energy [1]. Currently, 42.6% of Malaysia's electricity comes from natural gas, followed by 28.9% from coal, 18.6% from hydro, 6.3% from diesel and the remaining from renewable. This shows that significant amount of Malaysia's electricity comes from fossil fuel [2]. Another 6,682MW additional capacity of fossil-fuel based power plant will start operation between June 2019 and January 2023 [3], which will add to the carbon emission generation to the atmosphere.

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Bukit Merah dam was constructed in 1906 with the main purpose of providing irrigation water for double annual harvesting of paddy of 24,000 Ha of paddy field under the Krian Sungai Manik project. Other than agricultural purposes, it was also built to supply domestic and industrial demand in the Krian district. Two canals are connected to the dam, namely Terusan Besar (Main canal) and Terusan Selinsing (Selinsing canal). Bukit merah dam has a reservoir area of 41km^2, a capacity of 74.98Mm^3 and a catchment area of 480km^2[4].

Fig. 1 Bukit Merah Dam

Converting existing agricultural dam to generate electricity is a low-hanging fruit to mitigate increasing carbon dioxide emission from energy due to increasing energy demand and it is certainly not a new idea. The Government of United States conducted a survey in 2007 to estimate the capability of existing dams owned by the federal government across the United States. Through the study, it is estimated that from 871 existing federal facilities, a total capacity of 1230MW of electrical power generation is feasible technically and economically [5]. Other than estimating the energy output based on head and flow the stream, the costs varies based on location, which might include construction, licensing, fish and wildlife mitigation, recreation mitigation, historical and archeological mitigation, water quality monitoring, fish passage mitigation, fixed operation and maintenance, variable operation and maintenance and regulatory related costs. [6]

This study shows the potential of generating electricity from Bukit Merah dam, specifically from its main canal, based on the flow data of January until December 2016.

II. METHODOLOGY

This study was done based on the process flow in Figure 2 below:

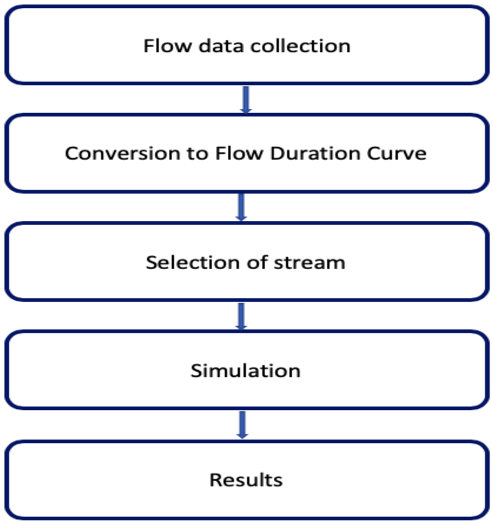

Fig. 2 Methodology of study

Flow data was obtained from Department of Irrigation and Drainage, Perak consisting of data from January 2016 until December 2016 on Terusan Besar (Main canal) and Terusan Selinsing (Selinsing canal).

The daily mean data is obtained from Department of irrigation and drainage (JPS), Perak and used to generate a flow duration curve. There are four (4) basic steps to create of a flow duration curve [7].

1. Acquisition of stream flow data,
2. Arrangement of flow data (in descending order)
3. Ranking of flow data
4. Obtaining frequency of occurrence(or exceedance probabilities)

This formula used to calculated frequency of occurrence:

$$F = 100[\frac{R}{N+1}]$$

Based on the flow duration curve obtained, the stream of a stable continuous flow is selected for the simulation to obtain the power output, electricity generation and capacity factor.

Simulation is done using RETScreen, a widely used tool for feasibility study of renewable project, developed by the Government of Canada. The stream flow data is input to the software, with the remaining parameters determined by the software. The software will then output the power and energy generated of three types of turbines, namely Kaplan, Propeller and Francis. The software will also produce their respective capacity factors.

Software user inputs the head and flow data based on the data collected and processed above and the flow data, turbine efficiency data, design coefficient, hydraulic losses, miscellaneous losses which includes the transformer losses and parasitic losses, also the generator efficiency and constant (density and acceleration due to gravity) needed for the calculations of the outputs are determined by the software as shown in Figure 3 below.

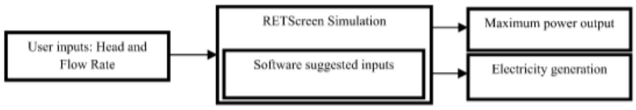

Fig. 3 User inputs and outputs of simulation

The simulation is done for three types of turbines, which are Francis, Propeller and Kaplan, based on the application chart in Figure 4.

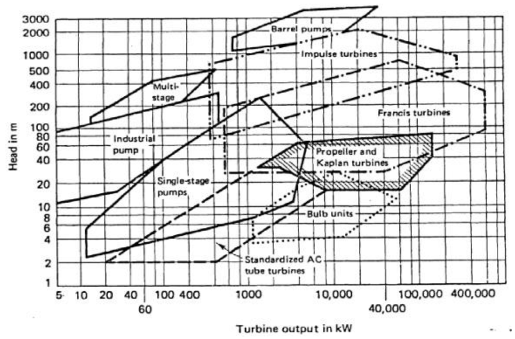

Fig. 4 Turbine Application Chart [8]

The software interface is shown in Figure 5 below.

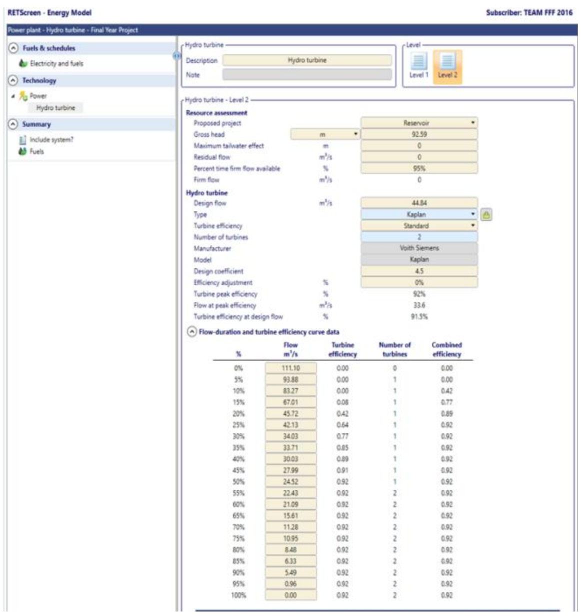

Fig. 5 User input in software

Maximum hydraulic losses, miscellaneous losses, generator efficiency and availability are also essential parameter in determining the accurate results. The RET Screen determine all those values as recommendation based on the input flow data [9].

III. RESULTS AND DISCUSSIONS

Results

The Bukit Merah site two main irrigation canal flow data (2016) is used to construct a flow duration curve, which is used to obtain the annual electricity that will be exported to grid. Figure 6and Figure 7 show a flow duration curve obtained using daily flow data of Bukit Merah site at Main Canal and Selinsing Canal.

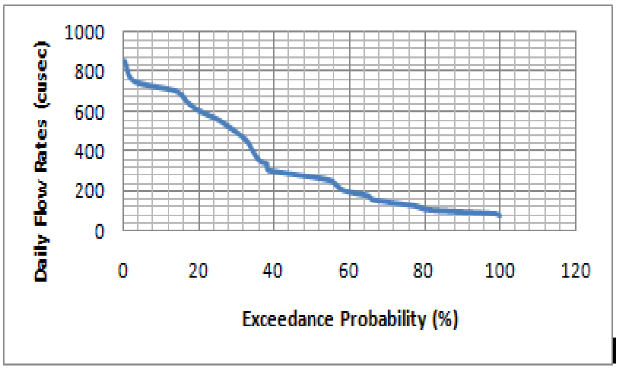

Fig. 6 Daily flow duration curve of Bukit Merah for Main Canal in 2016

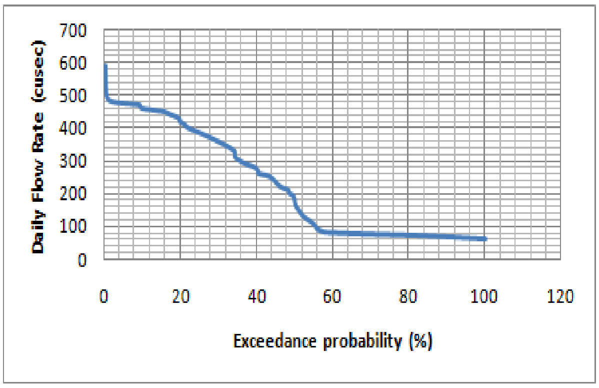

Fig. 7 Daily flow duration curve of Bukit Merah for Selinsing Canal in 2016

The flow duration curves show the maximum stream flow available for electricity production. For example, for at least 0% exceedance probability (0% exceedance probability and above), it is possible to obtain a stream flow of 24.0693m^3/s according to the Main Canal while 16.7069m^3/s for Selinsing Canal. Also, finding a stream flow of 16.9901m^3/s at least 20% of the time for Main canal while 11.6099m^3/s for Selinsing canal.

Putting together the two main irrigation canal flow data (Main Canal and Selinsing canal) daily flow duration curves, we obtain a more detailed and more explanatory flow duration curve shown in Figure 8.

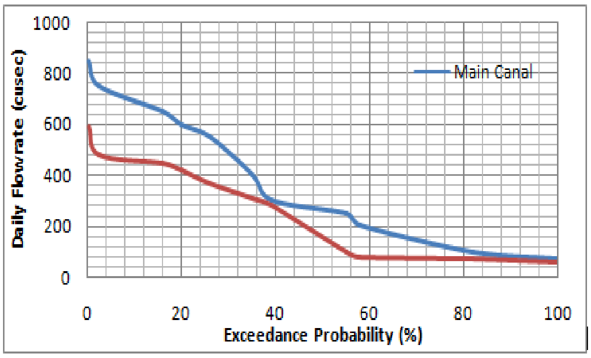

Fig. 8 Comparison of flow duration curve between the Main Canal and Selinsing Canal for 2016 daily flow rate data

Figure 8 shows the difference of the flow data of the two main irrigation canal. It compares flow rates at any exceedance probability for the two sets of flow rate data under consideration. Based on figure above, Main canal achieved more stable daily flow rates with higher flow rate compared to Selinsing canal. Thus, only Main canal flowrate data and gross hydraulic head was taken into consideration.

For the available head of 13.55 meters and design flow of 19.23 m^3/s, at the Bukit Merah site, the output of the hydropower plant for different turbine types processed by RET Screen is shown in Table 1 below.

Maximum hydraulic losses, miscellaneous losses and generator capacity are essential parameter in determine the accurate results for power capacity. These values are determined from recommend estimation by the RET screen software.

Table. 1 Simulation output for selection of turbine type using 2016 Main canal flow data

Turbine type	Power output (peak), kW	Capacity factor, %	Turbine peak efficiency, %	Turbine efficiency at design flow, %	Electricity expoerted to grid, Mwh
Kaplan	2222	36.1	92.8	92.4	7028
Propeller	2233	28	92.8	92.8	5471
Francis	1766	25.9	77.79	73.4	4002

In Figure 9 below, it is observed that for the flow data (2016) for Main canal, the propeller turbine type will deliver a higher power at its peak efficiency followed by the Kaplan turbine and the Francis type turbine is observed to have the least power capacity of the three turbine types. Deciding on a turbine type, however is not based on capacity only but also on the annual energy output and capacity factor.

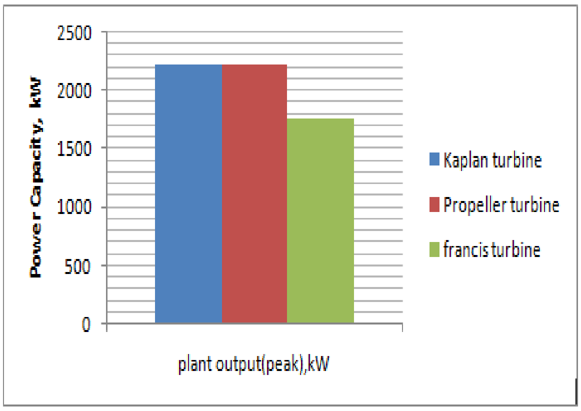

Fig. 9 Plant power capacities using different turbine types

Based on Figure 10 below, using the (2016) flow data, the annual plant energy output of the Kaplan turbine is the highest of the three turbine types. It is followed by the Propeller and Francis turbine types. This is attributed to the differences in the nature of the efficiency curves of the three turbine types.

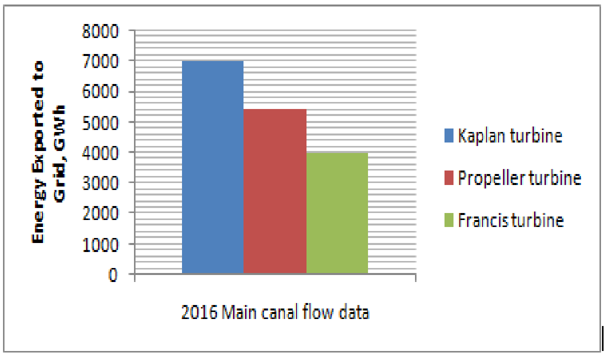

Fig. 10 Energy output using different turbine types

Based on Figure 11 below, it can be seen that the highest capacity actor is associated with the Kaplan. This implies that of all three turbines, the Kaplan turbine's actual annual energy output is closest to its highest possible annual energy output.

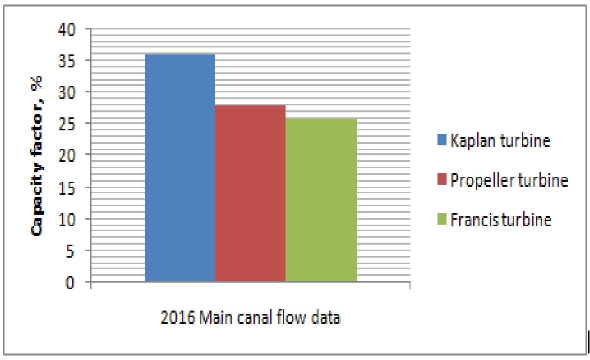

Fig. 11 Plant Capacity Factors using different turbine types

Based on the total energy produced per year and the capacity factors, it can be seen from that a Kaplan type turbine will be the best choice for this site as it will deliver the largest amount of energy (about 7028MWh), if the purpose of the dam is to provide continuous power. However, if it is to supply peaking power, propeller type turbine can produce slightly higher power output.

It is concluded that the Bukit Merah dam site, using Kaplan turbine will have a power capacity of 2222 kW and deliver energy of 7028 MWh to the national grid.

IV. CONCLUSIONS

This study shows the potential of generating electricity from existing dam initially constructed for agricultural irrigation. The potential power capacity available is 2222kW, with a potential generation of 7028MWh. Further study is needed on the design of the agricultural dam to incorporate power generation. Also, further study on the effect of water flow for irrigation is needed.

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