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DEVELOPMENT OF RESERVOIR OPERATION FOR BATANG AI HYDROELECTRIC PROJECT

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Abstract - Batang Ai Hydroelectric Project is meant to generate electricity. The Batang Ai Dam has a maximum capacity to generate around 108MW when it is fully operational. Efficient reservoir operation should be carried out very carefully in order to provide reliable water supply for power generation and water demand. The research of this project is to review the Batang Ai Dam storage conservation for the reservoir operation by using storage conservation simulation. The simulations are carried out with various outflow conditions using the principle of the storage equation. Lastly, the results from the simulation show that with proper regulation of the reservoir outflow, the Batang Ai Hydroelectric Project reliability to provide continuous power supply without shortage in water supply is assured.

***Keywords*:** Reservoir operation, Rule curve, Hydro-electric plant.

1.0 INTRODUCTION

Batang Ai hydroelectric project was constructed and operated by then Sarawak Electricity Supply Corporation (SESCO) in the year 1980. Previously, the company was known by this name before it underwent privatization and now it is a subsidiary company of Sarawak Energy Berhad (SEB). The dam that is designed as concrete-face rock-fill dam is located in Lubok Antu within the vicinity of Batang Ai National Park, Sarawak, Malaysia with the coordinates at 01°08′50″N and 111°52′26″E (Figure 1). The flood measurement at LubokAntu in maximum is around 939 m^3/sec. It has a dam height of about 85 m and a crest length of about 810 m. At the elevation level of (EL) 112 m, the reservoir surface area is 90 km^2 at full supply level (FSL). The minimum operating level (MOL) for this dam is at (EL) 98 m. For this dam, the gross storage volume is 2,870 million cubic meter, while the dead storage volume is 1,630 million cubic meter.

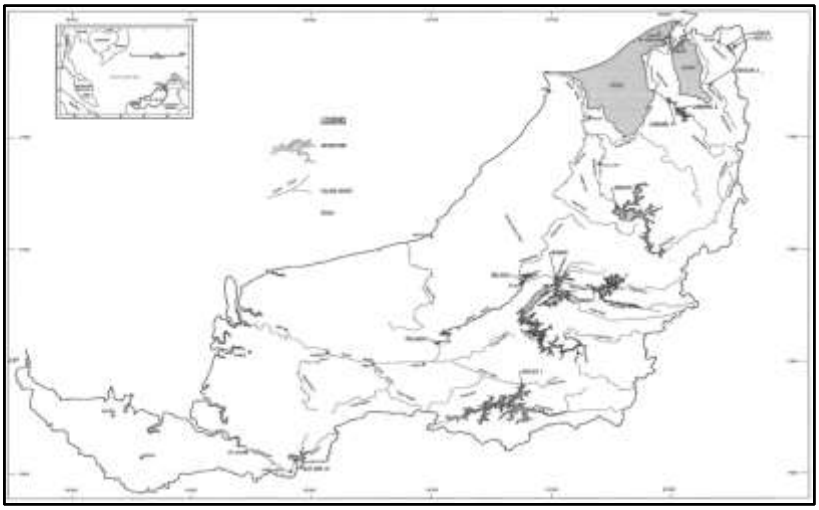

Figure 1 Locality of Batang Ai Reservoir and Hydroelectric Plant (Courtesy of Sarawak Energy Berhad)

This dam had installed generation capacity around 108MW which was consisted of four turbines. The hydroelectric project was initiated in year 1975, constructions began in year 1982 for the civil works and completed in year 1985 with the installation of all four turbines. The hydroelectric dam had been successful to operate the system starting from 1st December, 1985 until now. The financial provider was Asian Development Bank (ADB) and it involved resettlement of around 3,000 people from twenty six (26) longhouses who were affected by the project. The State-owned Sarawak Land Consolidation and Rehabilitation Authority (SALCRA) also helped to run the plantation on which the Iban were resettled. Therefore, the environmental issue had been mitigated by the time the hydroelectric dam was commissioned.

Reservoir operation is an important element in water resources planning and management. It is according to heuristic procedures and including rule curves. This provides general operation strategies for reservoir releases according to the current reservoir level, hydrological conditions, water demands and the time of the year. Storage conservation is the primary purpose of most reservoirs [1]. A rule curve shows the minimum water level requirement in the reservoir at a specific time to meet the particular needs for which the reservoir is designed. It is important to note that rule curve shall be followed except during periods of extreme drought and when public interest so requires [2].

2.0 LITERATURE REVIEW

The Batang Ai reservoir is part of the hydroelectric plant generating capacity in Sarawak. It comprises of several control variables which are guiding a sequence of releases to meet large amount of demands with various objectives such as flood control, hydropower generation and allocation of water to serve different uses in principal. The reservoir is considered to operate on a stand-alone basis, providing both base and peak, load generation on a 24 hour basis. This study is limited to optimize a single reservoir for a single purpose by analyzing the outflow and the imposed demand for the power generation operation at Batang Ai reservoir [3].

The main objective of reservoir should follow a proper set of rule curves so as not only to reduce the water shortage amount and duration for downstream demand but also to enhance the hydropower efficiency. The flows are controlled depending on the parameters of the reservoir system including the components such as the dam, spillway, inflow facility, and outlet works. The single purpose storage is a basic reservoir system shown as Figure 2. The inflow should have flow to a reservoir, typically uncontrolled if the reservoir is constructed on a river. Some dams are built off-stream and water is conveyed to the reservoir in a controlled manner. Usually, the elevation of the water level is depending on the controlling of inflow to the reservoir [4].

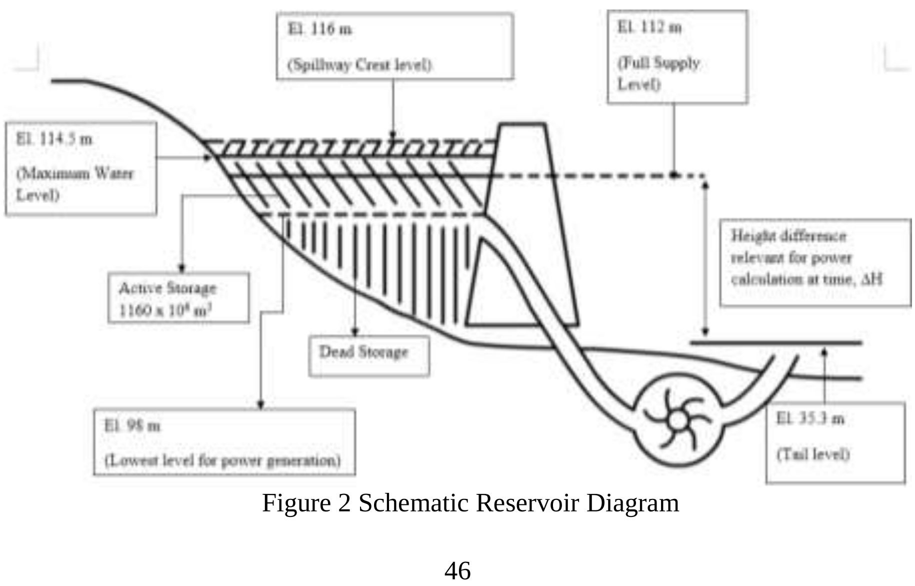

Figure 2 Schematic Reservoir Diagram

Once the reservoir is found beginning to approach an upper limit, the flow into the turbine gate is turned off if the inflow is able to be controlled. For the reservoirs that are located on river, the inflow cannot be controlled; therefore the reservoir must operate a flood control system usually includes outlet works and an uncontrolled spillway. When the outlet works are not able much to discharge outflow to lower the water level, then the water level would rise above the spillway; then the spillway gate is opened to discharge the flow which is dependent on the height of water above the spillway [4].

3.0 METHODOLOGY

There are a few steps of hydrological analysis that have to be applied in the reservoir simulation for performing the reservoir operation studies. Collecting the important data from available resources is needed in this study. Raw data obtained from SEB are studied and converted to the required parameters for the next step of analysis. Simulation for the Batang Ai reservoir storage conservation is carried out using spreadsheet (Microsoft Office Excel 2007). The first simulation is carried out to review reservoir storage reliability of supply based on the data provided. The subsequent simulations are based on different scenarios and then the results are analyzed to make comparison [5].

First simulation: If the reservoir level is below maximum water level (MWL) 114.5 m ASL

$$S_{t+1} = S_t + \text{Inflow} - \text{Turbine Discharge}$$

Second simulation: If the reservoir level is above maximum water level (MWL) 114.5 m ASL

$$S_{t+1} = S_t + \text{Inflow} - \text{Turbine Discharge} - \text{Spillway Discharge}$$

$$\text{Energy} = 9.81 \text{ x } Q \text{ x } \Delta H \text{ x } e \text{ x Time}$$

Where: S_t = Storage volume at the beginning of month in million cubic meter (mcm);
S_{t+1} = Storage volume at the end of month or the beginning of next month;
Q = Turbine Discharge = Outflow through the turbine in cubic meter per second (m^3/s);
Spillway Discharge is the outflow through the spillway;
ΔH = Height difference as shown in Figure 3;
e = Turbine efficiency; and
Time is one (1) month in Second

4.0 RESULTS AND DISCUSSION

This study has been conducted to show the Batang Ai Dam reservoir operation. From the analysis, the active storage is 1,160 million m^3 with the minimum 98 m ASL and maximum 112 m ASL operating levels are used. Therefore, the reservoir is operating over a range of 14 m. Different initial storage capacity has influence on the reservoir operation whether the operation for the subsequent years would encounter shortage of water. The standard operation rule is applied where the release of water is to meet the continuous power demand. If water release would lead to falling of operating level, water release is reduced to the minimum operating level which is 98 m ASL and if continuous power release would exceed the maximum operating level, water release is increased to just meet the maximum operating level at the end of the month. The operation of the reservoir depends on the amount of water in the active storage, inflow data, continuous power supply and the available secondary power before a decision of how much water can be released for the outflow. The simulations carried out in this study shows the effects of various outflow affects the reservoir operation based on the rule curves produced. The Figure 3 shows the comparison of rule curves for the two simulations. The rule curve for mean result of simulation period from standard operation has almost similar pattern with the rule curve for ideal outflow simulation. In the ideal outflow simulation, the turbine discharge is regulated, so that the reservoir water level at the end of the simulation period will be equal with the initial reservoir water level [1]. The simulation produces ideal rule curve.

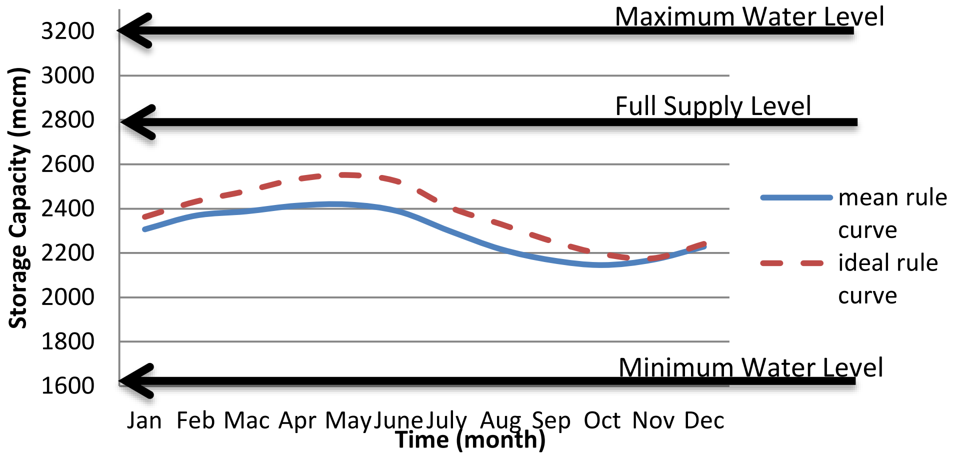

Figure 3 Comparison of Simulation with standard operation (mean rule curve) and ideal rule curve

Table 1 Summary of Comparison

Simulation	Water Level (m ASL)	Outflow (m^3/s)	Highest Storage (mcm)	Lowest Storage (mcm)	Generating Capacity (GWh)	Generating Capacity (MW)
Ideal	109.2 - 106	154-58	2,790	1,697	69-24	96-33
Mean	108.8 – 105.5	121-92	2,730	1,670	53-38	73-53

5.0 CONCLUSION

The Batang Ai Dam reservoir operation is reviewed. With the existing active storage and operating levels, the total energy production range is around 554 GWh annually. The standard operation rule is applied where the release of water is to meet the continuous demand, and if water release would lead to falling of operating level, water release is reduced to the minimum operating level (98 m ASL), and if continuous power release would exceed the maximum operating level, water release is increased to just meet the maximum operating level at the end of the month. The reservoir operation is mainly based on the rule curve and the power generating policy. Ideally, the outflow is essential to provide sufficient water demand to generate electricity. Simulation result shows the Batang Ai reservoir has 96-33 MV power generating capacity with the ideal outflow regulations.

It has been estimated on the basis of available monthly discharge records. Pending the eventual receipt from the Batang Ai Hydroelectric Project on the details of their proposed operating policy, the tail water level for Batang Ai is set at 35.3 m ASL. Batang Ai Hydroelectric Project is simulated up to year 2015. Further studies are recommended to optimize the reservoir operation with better option of the power system demand. The performance of the power station needs to be further investigated to fulfill machine efficiency. For the future, studies on the Batang Ai Hydroelectric Project of flood routing for the real time operation are also recommended.

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