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Regulation of Sutami Reservoir to Have a Maximal Electrical Energy

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ABSTRACT

This paper studied the operation of Sutami Reservoir. The methodology consisted of optimization energy which was due to turbine discharge and head of hydro electrical power. Results can use as the pattern of rule curve as the basic of reservoir operation. The rule curve considered optimization discharge, head and energy of hydro electrical power. Water resources development in Indonesia was targeted to supply water needs, which is the important aspect of water resources developments used for Irrigation. Water use for irrigation has also other advantages such as for hydro electrical power. Water restriction of surface water resources and higher cost of hydraulic structures intensify the need for an optimum capacity and operation for reservoir system. Thus, it was needed to allocate the water use as efficient as possible. To reach this target, it was needed to make a system model for optimization. Optimization analysis would give more information for allocating water of each objective function. Optimization of energy was carried out for yearly reservoir. Yearly reservoir was the reservoir which could reserve water during the rainy season then it was used in the dry season. For this kind of reservoir, water inflow was not the same quantity as the water outflow.
The methodology consisted of optimization Water allocation of hydro power which was due to turbine discharge and head of hydro electrical power. Results can use as the pattern of rule curve as the basic of reservoir operation. The rule curve considered optimization discharge of outflow, head and energy of hydro electrical power.

Keywords: Regulation, discharge, head, energy, optimization

INTRODUCTION

Water resources development in Indonesia was targeted to supply water needs. The water needs used for irrigation, hydro electrical power, industry, recreation, and daily human needs. Water is the source of life for all living organisms whose existence is absolutely necessary, with earth planet getting old a global warming occur which resulting in a reduced number of rainwater volumes [1].

The International meeting held by the "UNED" agency under the United Nations in 1996 is reviewing the relation between water management through economic mechanisms [2, 3]. This meeting resulted in the principle that water is an economic commodity and it is necessary to elevate activities programs and clear regulation in the water allocation and cost payment of the corresponding value. As for the water allocation and an appropriate water cost payment, it would implicate on the water use efficiency improvements that support the preservation of existing water sources [4].

Pigram [5] stated in a Water Policy Agreement symposium in Australia that the payment of the cost of water policy should be conducted in accordance with the settings to get the water distribution continuity. Mc. Neill [6], stating that water is an economic commodity, for the calculation of the cost of water, there are three components, namely the distribution, processing and transmission. Beecher [7], review of water price optimization interest based on their needs, setting water requirements affect the amount of water prices. Suparmono [8] states that water resource management should be through a Hydro Politics approach where the water policy regulation is not only controlling the water number or water volume but also financing is a factor that should not be overlooked. Hernowo [9] said that the water resources management gap, need to be solved by a policy settings and water adjustment as an economic commodity.

Some opinions above underlying the idea to investigate further the effects of the water price toward the water allocation. While a study that are discussing about water allocation and the full price of water has not been investigate yet.

Some of few studies that have been conducted such as a study carried out by Lund (1998), Hatmoko [10], Labadie [11], Leon [12] mostly covers only specific optimization study water allocation without considering the water price. So it is clear that there is a gap between the needs of the present with the existing ones. Research needed now, are the research that would resulted in:

- A definite water distribution or water allocation rules on river systems by considering water as an economic commodity.
- A Certainty of water allocation and water price as an optimization result as a combination of water availability and water prices simultaneously.
- An easily optimization studies used by the interested parties.

A water optimization model is needed to get the water distribution and certain water price rules. An optimization model that is easy to use by taking one of the methods of linear optimization. The linear optimization model is often used on the water management optimization but the optimization is still using a variable allocation and does not use a price variable to get the optimal results, so the price factor is only used as a supplement or coefficients without being able to know the exact optimal water price.

The linear optimization in the new model would optimize both the water allocation and the water price which is maximizing the water allocation and minimize the water price. Water allocation and water price is functioned as an optimized variable, to compare the old and new optimization model in water management optimization model in the reservoir with the irrigation users (1), hydropower (2), flood control (3), tourism (4) and drinking water (5). The optimization basic form was described as follows.

The important aspect of water resources developments used for hydro electrical power. Water use for hydro electrical power gave more advantage because it would decrease the use of gasoline. Restriction of surface water resources and higher cost of hydraulic structures intensify the need for an optimum capacity and operation for reservoir system. Thus, it was needed to allocate the water use as efficient as possible. To reach this target, it was needed to make a system model for optimization. Optimization analysis would give more information for allocating water of each objective function. The study was conducted at Sutami Hydro Power, East Java Indonesia. Figure 1 shows the Sutami Reservoir location map.

Figure 1: Sutami Reservoir Location Map

MATERIAL AND METHODS

Some data were needed to carry out the optimization instead of map of study location, map of reservoir location, discharge, reservoir data and area of irrigation. Analysis data was included energy of hydro electrical power, water need for irrigation, human life etc. Optimization of hydro electrical energy was carried out for yearly reservoir. Yearly reservoir was the reservoir which could reserve water during the rainy season than it was used in the dry season. For this kind of reservoir, inflow was not the same as outflow.

Linear programming was very important as the basic of developing operation research. It was known as a deterministic tool because all parameters used in this program was determined certainty. In fact, there was never seen certainty case, so that Linear Programming was used as analysis of post optimization for making decision. The development of mathematical modeling was begun with answering the three questions as follows:

1) What would be devoted by the model? In the other words what variables was needed for this case?
2) What were the constraints to involve this boundary of the system?
3) What was the objective function for reaching the optimized feasible solution?

The step by step to carry out Linear Programming is as follow [4]:

(1) To build optimization models (Figure 2);
(2) To determine the resources which would be optimized (for this case study are irrigation and hydro electrical power);
(3) To calculate the quantities of input or output for every kind of activity unit; (4) To build the mathematical modeling. The formulation of optimization model for the case above was as below:

The objective function was

$$\text{Max } E = E1 + E2 + E3 + E4 + E5 \ldots\ldots\ldots + .En \qquad (1)$$

Subject to

$$S\ min < Sn < S\ max \qquad (2)$$

$$\text{Outflow turbine} > \text{Q downstream} \qquad (3)$$

$$\text{Total outflow 1 year} = \text{Total inflow 1 year} \qquad (4)$$

with

E = Energi per year (KWH)

$$E = 9.8\ e\ Q\ H\ x\ t \qquad (5)$$

and

9.8 = acceleration of gravitation (m/s^2)
E = effisiency of turbine and generator
Q = turbine inflow/ discharge (m^3/s)
H = effective head of hydro electrical power (m)
t = time (hour)

E1,E2, E3,………+En	= monthly energy.
Sn	= monthly storage (m^3)
S min	= minimal storage (m^3)
S max	= maximal storage (m^3)
Out flow turbine	= turbine outflow/ discharge (m^3/s)
Q dowstream	= water need in the downstream of reservoir (m^3/s)

RESULT AND DISCUSSION

The optimization of reservoir outflow was carried out by implementing the solver available for the Microsoft Excell software. This small program addition is available in the Excell program Excell. Before using the solver, a table should be elaborated to facilitate the mathematical functions as variables or constraints. Table 1 shows the real model in the solver program to execute just open solver and fill the solver clipboard with number of cell as need.The constraints such as monthly inflow at cell (C10-C21) which is given a series of values for the monthly inflow from January until December (C10 is filled with 49.47 10^6 m^3). The maximum storage (C5) is given a value of 109.92 10^6 m^3. The minimum storage (E5) is given a value of 30 10^6 m^3. The downstream need (F5) is given a value of 55.90 m^3/sec. The maximum water elevation (H5) is about 27.25 m high. The minimum water elevation (I5) is as high as 260 m. The variables such as monthly energy (M10-M21), where as an example M10 was given a value of 26.26 10^6 Kwh and the outflow discharge range is (K10-K21) where as an example K10 is given a value of 55.56 m^3/sec. After all constraints cell be filled into the spreadsheet cells then the simulation is ready to be executed. The optimal result of the outflow discharge is seen at cell K10 until cell K21 which is representing outflow discharge for each month with a value of 56.56 m^3/sec, 56.29 m^3/sec, 69.33 m^3/sec, 79.93 m^3/sec, 89.73 m^3/sec, 76.54 m^3/sec, 58.63 m^3/sec, 42.10 m^3/sec, 37.98 m^3/sec, 34.62 m^3/sec, 34.49 m^3/sec and 43.22 m^3/sec respectively. While the optimal energy produced is presented in cell M10 till cell M21. Cell M10 till cell M21 is representing the energy cultivated based on this observation model with a value of 26.62 10^6 KWh, 27.21 10^6 KWh, 34.96 10^6 KWh, 41.84 10^6 KWh, 47.99 10^6 KWh, 39.80 10^6 KWh, 31.55 10^6 KWh, 21.99 10^6 KWh, 20.28 10^6 KWh, 18.14 10^6 KWh, 17.73 10^6 KWh and 23.11 10^6 KWh respectively. The solver result for the optimization of the energy produce could be seen in Table 1 and Figure 2 below.

Table 1: Optimization of hydro electrical energy at Sutami Reservoir, Indonesia

1	OPTIMIZATION RESULT										
2	B	C	D	E	F	G	H	I	K	L	M
3	m^3/sec	10^6 m^3	m^3/sec	10^6 m^3	m^3/sec	10^6 m^3	m	m	m^3/sec	10^6 m^3	10^6KWh
4	Q max	S Max	Q min	S Min	Q need	S need	El.Max	El.Min	Out mean	Out Opt	E. OPT
5	42.407	109.92	12.00	30	55.90	671	272.50	260	56.61	1760.8	351.20
6		$S_n = S_{(n-1)}$ + In -Out			S O = S_n - Smax						
7		I	Sn	I - O	SO						
8		m^3/sec	m^3/sec	m^3/sec	m^3/sec	10^6 m^3	m	m	m^3/sec	10^6 KWh	10^6 KWh
9	Month	Inflow	Sn	□S	Spill Out	S Res	Elevation	Heff	O Opt	E.OPT	Energy
10	December	49.47	12.00	-7.10	0.00	31.10	263.54	55.53	56.56	26.62	26.62
11	January	61.27	16.98	4.98	0.00	44.00	265.00	56.29	56.29	27.21	27.21
12	February	80.53	28.18	11.21	0.00	73.05	268.93	69.33	69.33	34.96	34.96
13	March	94.13	42.38	14.20	0.00	109.86	272.49	79.93	79.93	41.84	41.84
14	April	93.30	42.407	3.57	3.54	109.92	272.50	88.56	89.73	47.99	47.99
15	May	80.00	42.407	3.55	3.55	109.92	272.50	75.51	76.45	39.80	39.80
16	June	58.63	42.407	0.00	0.00	109.918	272.50	55.85	58.63	31.55	31.55
17	July	40.50	40.81	-1.60	0.00	105.77	272.03	42.10	42.10	21.99	21.99
18	August	33.57	36.39	-4.41	0.00	94.33	270.73	37.97	37.98	20.28	20.28
19	September	28.70	30.47	-5.92	0.00	78.98	268.98	34.60	34.62	18.14	18.14
20	October	27.13	23.12	-7.36	0.00	59.92	266.81	34.47	34.49	17.73	17.73
21	November	32.10	12.00	-11.12	0.00	31.10	263.54	40.70	43.22	23.11	23.11
22	December	679.33		0.00	7.10			670.82	679.33	351.20	351.20
23	Total	1760.8	79.82	0.00	18.40	79.82		1738.77	1760.8		
24	10^6 m^3	56.86	30.80	0.00	0.59	79.82	269.13	55.90	56.61	29.27	29.27
25	Average	49.47	12.00	-7.10	0.00	31.10	263.54	55.53	56.56	26.62	26.62

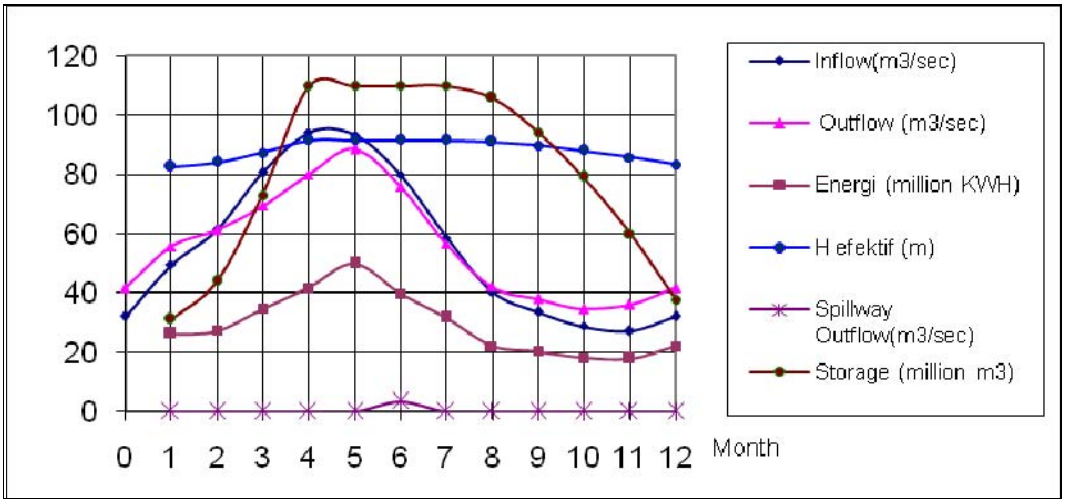

Figure 2: Optimal Reservoir Regulation Curve

The rule curve as an optimization result could be used for the reservoir operation such as determining the water reservoir elevation level and also to calculate the water discharge to be drawn from the reservoir. The important thing is that the energy produced per month can be read as a prediction at the rule curve.

CONCLUSIONS

The results of optimization were very important to know the optimized energy of hydro electrical power. Regulation of reservoir as one of the optimized results was needed to get the pattern of reservoir operation. The results was included the outflow from reservoir, water level at reservoir and Optimal Energy of hydro electrical power.

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