Optimization of Hydroelectric Power Generation, Case Study of Roseires Dam in Sudan

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ABSTRACT

Water reservoirs are large pools of water created stream or river catchment's areas and torrential rains and for storing water for use in many ways, and perhaps electric power generation is one of the most important uses of these reservoirs and for agriculture. That is extremely beneficial considering a rare and limited economic resources. Applied stochastic processes model has been applied in the work of Roseires dam, in order to develop a system to generate the highest possible power in the resources available. The current paper aims to apply another model, which is a dynamic programming model to verify the possibility of developing the same system and thus generate the highest possible electricity from the reservoir.

Data collected from the Ministry of Irrigation and the National Electricity Cooperation and international information network during the years 206-2007.

1. Introduction

Studies take importance of water resources; the studies improvise mathematical models for designing and managing complicated systems, which involve many variables. One of studies deal with Dynamic programming models, and the goal of this study is to introduce Dynamic model for generating hydroelectric power. In 1952 Bellman introduced the theory of dynamic programming following that Young (1967) used the dynamic programming to obtain the optimal operation policy for multiple dams assumes the capacity of storage is known and the study had been applied in California. Mobashori (1970) developed Hall's models to obtain better storage policy, but the use of stochastic dynamic programming started in 1955 by little. In (1973) Yeh applied the (S.D.P) for maximizing the generated power and in (1980) Dogli used (D.P) depended on forecast values for inputs.

2. The Dynamic Model

The objective function is to achieve maximum production when operating the system, objective function of dams depends on standard for measuring the efficiency of dam for maximization.

If we assume (Z) is the Objective function then

$Z = Max\sum_{i=1}^{n} P\omega_n$ where

$P\omega_n$ = Total of generated power subject to inputs, outflow, evaporation and other constraints

This objective function can be written as

$$Z = Max\sum_{i=1}^{n}\sum_{j=1}^{n} Y_i\, h_{i,n} Y_{i,n}$$

Where

Sort of dam	Constraint of mathematical model
Single	$S_{n+1} = S_n + X_n - Y_n - D_n - V_n$
Two sequential dams	$S_{1,n+1} = S_{1,n} + X_{1,n} - Y_{1,n} - 1_{1,n} - Y_{n,2} - V_{2,n}$
Multiple sequential dams	$S_{i,n+1} = S_{i,n} + X_{i,n} + Y_{i-1,n} - 1_{i,-1,n} - Y_{i,n} - D_{i,n} - V_{i,n}$
Parallel dams	$S_{i,n+1} = S_{i,n} + X_{i,n} - Y_{i,n} - D_{i,n} - V_{i,n}$

Such that

S_n = Storage of water

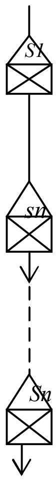
X_n = Inputs of water

Y_n = Output of water

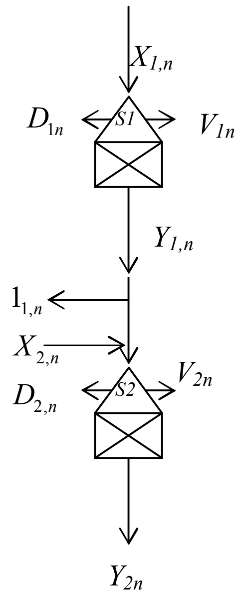
D_n = Water had been taken from the Dam

V_n = Evaporation of water

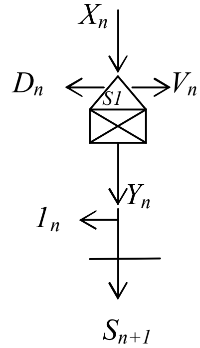
The above symbols is represented at the dams in the following figures



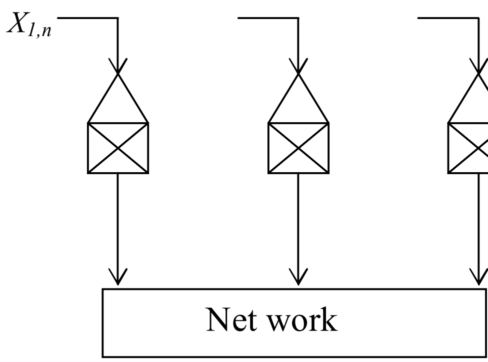
A plan for multi Dams



A plan for two Dams



A plan for single Dams



A plan for parallel Dam

Figure (1) Plans for different dams

Table (1) The Adjusted levels of waters at Roseires dam

Volume of water	Adjusted level	Level
0.038	466.22	465
0.060	468.14	467
0.350	474.35	471
0.620	476.26	473
0.950	477.89	475
1.300	479.13	477
1.780	480.09	479
2.000	480.57	480
2200	481.04	481
0.076	468.61	
0.068	468.61	
0.162	471.48	
0.276	473.39	
0.294	473.87	
0.332	474.35	
0.512	475.78	
0.514	475.78	
0.532	475.78	
0.624	476.26	
0734	477.22	
0.934	477.70	
0.974	478.18	
0.994	478.18	
1.212	478.65	
1.412	479.61	
1.454	479.61	
1.674	480.09	
1.874	480.57	
1.877	480.57	
1.885	480.57	
2.005	480.57	

The (N.E.C) program was achieved by calculating the difference between the upper and lower levels, and then applied the equation as in their table, HEAD Vs. S.W.C (Specific Water Consumption).

Here we determine the differences between levels, which are the effected charge. In addition, the efficiency of turbines* water density*.

Gravity = γ (coefficient of transferring).

Table (2) Transformation of non linear for variables

Water Volume Y	Level X	Log Y	Log X
0.038	465	-3.270	6.142
0.060	467	-2.813	6.146
0.350	471	-1.050	6.155
0.620	473	-0.478	6.159
0.950	475	-0.051	6.163
1.30	477	0.262	6.167
1.78	479	0.577	6.171
2.00	480	0.693	6.173
2.200	481	0.788	6.176

When we apply the least squares estimation method for Log Y and Log X we get

$\alpha = 6.17$ and $\beta = 0.0077$

Then

$$
\begin{aligned}
EL_n &= e^{6.17+0.0077 LnS_n} \\
&= e^{6.17} \times e^{0.0077 LnS_n} \\
&= e^{6.17} \times S_n^{0.0077} \\
&= 478.18 \times S_n^{0.0077}
\end{aligned}
$$

For the Rosiers dam, the generating electricity by the two methods is shown in the following tables

Table (3) Generating electricity by using stochastic process model

Month	Storage of water at the beginning of the month	Storage of water at the end of the month	Adjusted level	Effected charge		Optimal outflow	Production mw/h
				H	S.W.C		
Jan	2.200	1.874	481.04	34.04	12.7	0.933	78188
Feb	1.874	1.412	480.57	33.57	12.7	0.878	69133
Mar	1.412	0.934	479.61	32.61	12.9	0.831	64418
Apr	0.934	0.532	477.70	30.70	13.2	0.730	55303
May	0.532	0.276	475.78	28.78	14.2	0.849	59788
June	0.276	0.068	473.39	26.39	15.7	1.808	115159
July	0.068	0.068	468.14	21.14	21.0	6.630	208320
Aug	0.068	0.068	468.14	21.14	21.0	14.562	208320

Sept	0.068	1.885	468.14	21.14	21.0	9.550	208320
Oct	1.885	2.200	480.57	33.57	12.7	5.252	208320
Nov	2.200	2.005	480.04	34.04	12.7	2.348	184.881
Dec	2.005	2.200	480.57	33.57	12.7	1.315	103543
Total							**1563693**

By using of dynamic programming model for the generation of electricity, we reach the results in the following table

Table (4) Generating electricity by using dynamic programming model

Month	Storage of water at the beginning of the month	Storage of water at the end of the month	Adjusted level	Effected charge		Optimal outflow	Production mw/h
				H	S.W.C		
Jan	2.200	1874	480.04	34.04	12.7	0.967	76141
Feb	1874	1.412	480.57	33.57	12.7	0.854	67244
Mar	1412	0.934	479.61	32.61	13.7	0.816	63750
Apr	0.934	0.532	477.70	30.70	14.2	0.716	52262
May	0.532	0.267	475.78	28.78	15.5	0.765	53873
June	0.276	0.068	473.39	26.39	21.0	1.755	113225
July	0.068	0.060	468.61	21.61	21.0	6.004	208320
Aug	0.060	0.060	468.14	21.14	21.0	14.424	208320
Sept	0.060	1.877	468.14	21.14	21.0	9.514	208320
Oct	1.877	2.200	480.57	33.57	12.7	6.232	208320
Nov	2.200	2.005	481.04	34.04	12.7	2.331	183543
Dec	2005	2.200	480.57	33.57	12.7	1.529	120393
Total							**1563711**

From the tables we note that the results are approximately identical, therefore we can arrive to the maximum electricity generation either by using stochastic model or dynamic model and this assured the opinion of Jay Forster about the dynamic model.

3. Conclusion

The maximum production of electricity is achieved when 45–78% of the stored water used by using the pervious two models. Economic advantage is achieved here, especially under precious and rare single limited water source as in the case of the Nile River. Consideration should given to such a model as part of an optimum control paradigm. The National Electricity Authority is called for to consider the two mathematical models, stochastic or dynamic and more studies may be carried-out when the relation between the volume and the level of water is nonlinear.

4. References

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