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Relationship between Power Generation and Reservoir Elements in the Jebba Hydroelectric Reservoir, Nigeria

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Abstract - Electricity came to Nigeria (in 1896)15 years after it got to England. Despite its long history in Nigeria, electricitygeneration is still at its low ebb with power outages being the order of the day.Power generation is a product of reservoir operation;hence, the understanding of the interactions between them iscrucial to energy supply. This study examines the interactions between electricity generation and reservoir elements in Jebba dam, Nigeria. Monthly data were collected on 11 reservoir elements and on monthly electricity generation from (1989-1999). Factor-multiple regression and factor-stepwise regression methods were adopted in the interpretation of the relationships between power generation and reservoir elements. A total of 12 factor analytical procedures were carried out, this representone operation per month. This allowed the exhibition of the relationships on monthly basis. The factor analysis reduced the monthly variables to between 3 to 4 orthogonal factors. All the factors were important to the explanation of the variance with the percentages of explanations ranging between 79 and 92%. The result of the regression analyses showed that reservoir elements were strong predictors of power generation in all the months with the exception of April. The percentage explanation for factor multiple regression range from 13 to 98%; while that of factor stepwise regression ranges from 57.8% to 95.7% , with the exception of April when all the variables entered the equation. Twenty one reduce - rank (eqs. 5-26)power generation models were developed for predicting power generation in Jebba.

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Strictly as per the compliance and regulations of :

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I. Introduction

Electricity in Nigeria dated to 1896 when it was first generated in Lagos 15 years after it was introduced to England. By 1928 the NESCO started operation in Jos, in 1951 ECN was inaugurated and this later transformed into National Electricity Power Agency in 1972. Despite its early arrival electricity has a slow pace of development in Nigeria. For over 20 years before 1999, the Nigerian power sector did not witness any substantial investment. This brought power to a deplorable condition. For example, in 2001 generation went down from the installed capacity of 5,600 mw to an average of about 1,750 mw compared to a load demand of 6,000mw across the country. Only 19 out of the 79 installed generating units were in operation (Sambo, 2008). Hence, electricity generation, distribution and transmissionhave been a serious problem in Nigeria. The demand for electricity in the country far outstrips the supply.

The problem with Nigeria power sector ranges from corruption, negligence, climate change, political restiveness, inefficient water management scheme among others. Water management in power generation is very crucial to power generation. Inefficient planning can bring about unutilized water; a condition which apart from causing low power generation can also endanger the dam and loss of enormous water in the reservoir to evaporation.

Efficient water management can only be realized when a sufficient understanding of the complex interactions between reservoir elements and electricity generation is understood (Sharma, 1995; Patra, 2001; Panigraphi; 2008). Causal relationships exist between hydroelectricity and reservoir elements. For example the reservoir inflows which comprises of peak inflow, average inflow and minimum inflow largely determine the amount of water that enters into the reservoir. The inflowsin turnscontrol the amount of water that determines the reservoir level, the pressurehead and the reservoirstorage balance. The outflows comprising of peak outflow, minimum outflow and average outflow are crucial to reservoir balance, the reservoir useful life, the reservoir discharge and the aquatic ecosystem in the downstream area. It will affect the rate of inundation of flooding, water scarcity, erosion, siltation, flood plain contraction, and fishery. And also control domestic and agricultural water supply in the downstream area. Reservoir evaporation and important reservoir element is a signal to how efficient water is used. Reservoir evaporation willalso impact on water availability in the reservoir.

This present study will investigate the relationships between reservoir elements and electricity generation in Jebba dam reservoir with a view to predicting monthly power generation in the hydropower station.

II. The Study Area

Jebba reservoir is located on latitude 9° 35` and 9° 50`N and longitude 4° 30` and 5° 00` E. It located on

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river Niger, Nigeria (Fig. 1). It is a 540mw dam. Jebba is underlain by Basement

Fig.1 : The Niger Basin

(*Adapted fromEmoabino, I. U., Alayande, A. W. and O. A. Bamgboye (2007)*)

Complex rocks such as porphyritic granite, mica, quartzite, etc (Sagar, 1985; NEDECO, 1959; Imevbore, 1970). It has an estimated surface area of 303km^2 and a volume of 3.31x 10^{9}m^3. The maximum depth is 105m and a mean depth f 11m (Ita, et al 1984).

According to NEDECO (1959) and NEDECO and Balfour Beatty (1961) 2 patterns are discernable in the seasonal hydrological regime of river Niger in Jebba. In the months of May to October rainfall in the northernparts of Nigeria south of Niamey produces flood that quickly reaches Jebba area witha peak of 4,000-6,000 m^3 s^{-1} in September to October (Figs 2,a,b,c). This flood water is laden with silt and clay sediment and its of high turbidity. Due to its colour, it is locally called 'white flood'. The second flood originates from the rivers headwater region from rivers of high

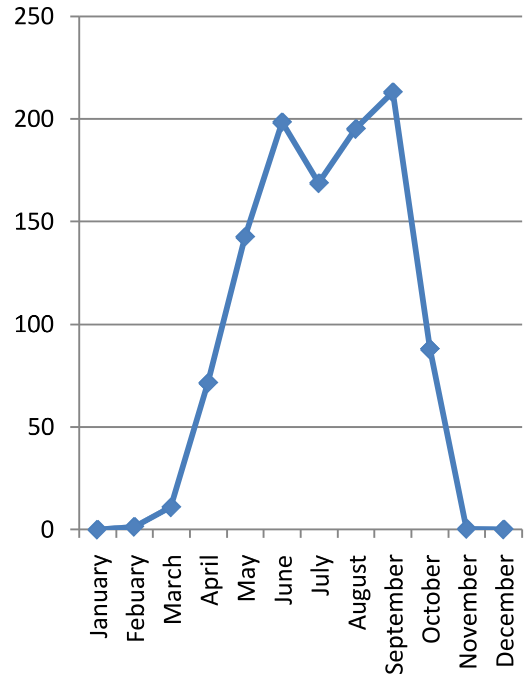


Fig 2(a) : Pattern of monthly rainfall in Jebba

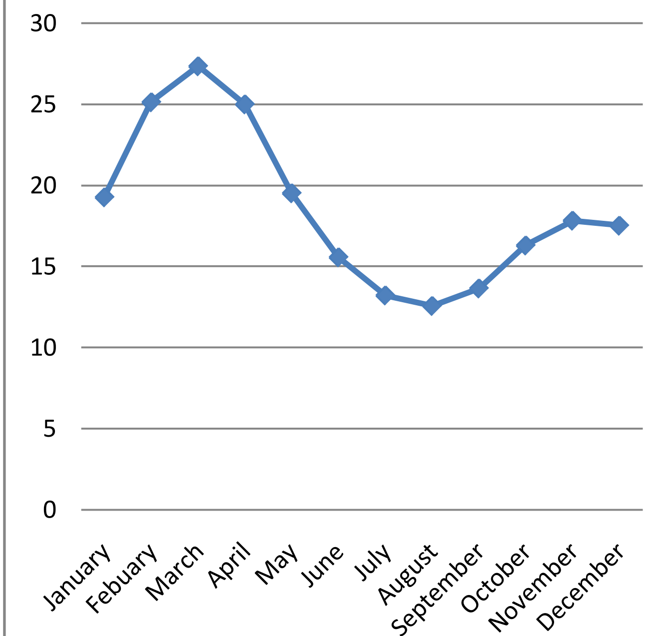


Fig.2 (c): pattern of monthly evaporation in Jebba.

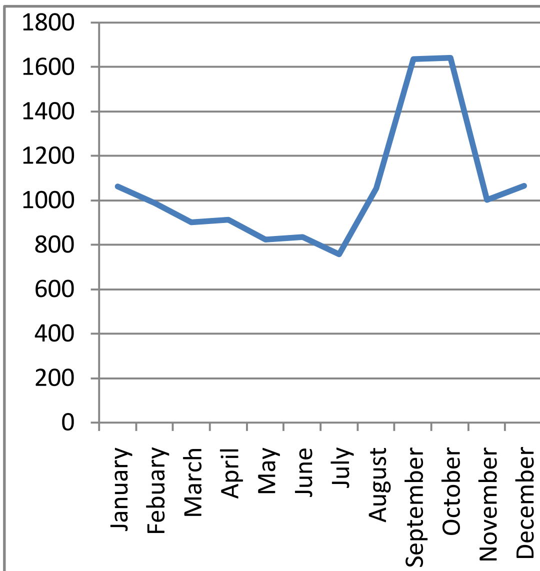


Fig. 2(b) : pattern of Monthly inflow in Jebba

Fig. 2(a., b., c.) : Monthly patterns of Hydrometeorological variables in Jebba.

annual rainfall in the Fouta Djallon highlands in Guinea and passes through sub-arid region and deltaic swamps in Timbuktu. In this area much of the silt is lost to evaporation and infiltration. Little water is added before it reaches Kanji in November with a peak flow of 2000 $m^3 s^{-1}$, the water is relatively clear known as black flood (Oyebande, et al, 1990; Mbagwu, et al, 2000;; Olaosebikan, et. al., 2006). These floods lead to high water levels which always give rise to water release at the dam sites which eventually have negative consequences on the study area. The flow regime of the River Niger below the Jebba dam is governed by the operations of the Kanji and Jebba Hydroelectric schemes and runoff from the catchments. The annual 'white floods' event which usually sets in July and peaks in September does not maintain the same frequency as almost every four years the flood sets in with greater velocity, this lead to the dam overflowing its banks. This caused destruction of sugar cane plantation by inundation of sugar cane field, irrigation pumps and submerging of farming areas occupied by the villages.

According to Lawal and Nagya (1999), Bolaji (1999), Olukanni and Salami (2008) and Sule, et. al. (2009) the havoc wreaked by the flooding of the lower Niger in 1998 and 1999 also has its effect on social services to the people of the area. For example schools in about 32 and 52 villages were submerged in the flood of 1988 and 1999 in the downstream of Jebba respectively, while schooling for fleeing villagers remain disrupted and the hospitals were not spared by flood.

III. Materials and Methods

The data required in this study are mainly data on the monthly electricity generation in the power dam and information on the reservoir elements. These data were collected from the Hydrology Department of Power Holding Company, Jebba Hydropower Dam. A total of 10 hydro engineering/ reservoir elements were studied on monthly basis in this study. These are minimum inflow, storage balance, evaporation, average outflow, peak inflow, peak outflow, reservoir level, average inflow, minimum evaporation outflow and discharge. These parameters were sampled for 10 years (1989-1999).

The data collected were subjected to both descriptive and inferential analyses. The descriptive methods used in this study are: mean , frequency analysis and graphs. The inferential methodis the factor-regression model, which is combination of factor analysis and multiple regression and stepwise regression methods.The factor regression model(West, 2002; Carvalho, 2008) or hybrid factor model (Meng, 2011) is a special multivariate model with the following form.

$$\mathbf{y}_n = \mathbf{A}\mathbf{x}_n + \mathbf{B}\mathbf{z}_n + \mathbf{c} + \mathbf{e}_n \quad \text{.....(eq.1)}$$

where,

$\mathbf{y}_n$ is the n-th $G \times 1$ (known) observation.

$\mathbf{x}_n$ is the n-th sample L_x (unknown) hidden factors.

$\mathbf{A}$ is the (unknown) loading matrix of the hidden factors.

$\mathbf{z}_n$ is the n-th sample L_z (known) design factors.

$\mathbf{B}$ is the (unknown) regression coefficients of the design factors.

$\mathbf{c}$ is a vector of (unknown) constant term or intercept.

$\mathbf{e}_n$ is a vector of (unknown) errors, often white Gaussian noise.

The factor regression model can be viewed as a combination of factor analysis model ($\mathbf{y}_n = \mathbf{A}\mathbf{x}_n + \mathbf{c} + \mathbf{e}_n$ ..... (eq2)) and regression model ($\mathbf{y}_n = \mathbf{B}\mathbf{z}_n + \mathbf{c} + \mathbf{e}_n$ ... (eq3)).

Alternatively, the model can be viewed as a special kind of factor model, the hybrid factor model

$$\mathbf{y}_n = \mathbf{A}\mathbf{x}_n + \mathbf{B}\mathbf{z}_n + \mathbf{c} + \mathbf{e}_n$$

$$= [\mathbf{A} \quad \mathbf{B}] \begin{bmatrix} \mathbf{x}_n \\ \mathbf{z}_n \end{bmatrix} + \mathbf{c} + \mathbf{e}_n$$

$$= \mathbf{D}\mathbf{f}_n + \mathbf{c} + \mathbf{e}_n \quad \text{.......... (eq. 4)}$$

where, $\mathbf{D} = [\mathbf{A} \quad \mathbf{B}]$ is the loading matrix of the hybrid factor model and $\mathbf{f}_n = \begin{bmatrix} \mathbf{x}_n \\ \mathbf{z}_n \end{bmatrix}$ are the factors, including the known factors and unknown factors.

Factor analysis was usedfor data reduction purposes: To get a small set of variables preferably uncorrelated from a large set of variables most of which are correlated to each other in the data set. Multiple regression in form of factor regression (where the orthogonal factor scores were used as input into the regression model) was used to study the relationships between reservoir elements and electricity generation. Stepwise regression analysis was used as a (reduce-rank model) to reduce and to model power generation in Jebba.

IV. Result and Discussion

The percentages of explanations and the factor defining variables of the monthly factor analysis equations are presented in Table 1.

Table 1: Percentage Contribution and Cumulative Percentage Contribution of Monthly Factor Defining Variables of Monthly Reservoir Elements in Jebba

S/N	Month	Factors Defining Variables		Cumulative Contribution (%)
		Reservoir Elements	Percentage Contribution (%)	
1	January	1. Peak Inflow	49.6	82.6
		2. Storage Balance	20.0	
		3. Evaporation	12.9	
2	February	1. Minimum Inflow	33.6	
		2. Storage Balance	24.9	90.7
		3. Average Outflow	21.7	
		4. Peak Inflow	10.3	
3	March	1. Minimum Inflow	33.6	
		2. Storage Balance	25.0	91.1
		3. Average Outflow	21.7	
		4. Peak Inflow	10.7	
4	April	1. Peak Outflow	37.4	
		2. Storage balance	26.4	79.2
		3. Average Inflow	15.4	
5	May	1. Peak Inflow	27.5	
		2. Reservoir Level	25.5	89.7
		3. Evaporation	11.2	
		4. Average Outflow	25.4	
6	June	1. Minimum inflow	24.9	88.8
		2. Average Outflow	23.9	
		3. Discharge	16.2	
		4. Reservoir Level	23.7	
7	July	1. discharge	37.4	88.0
		2. storage balance	36.4	
		3. minimum outflow	14.2	
8	August	1. Average Outflow	37.4	
		2. Storage Balance	36.4	88.0
		3. Discharge	14.2	
9	September	1. Minimum Inflow	33.0	
		2. Average Outflow	30.8	87.4
		3. Reservoir Level	23.6	
10	October	1. Peak Inflow	38.4	
		2. Storage Balance	25.0	84.3
		3. Average Inflow	20.9	
11	November	1. Average Inflow	27.9	
		2. Peak Inflow	27.4	80.9
		3. Discharge	25.4	
12	December	1. Peak Outflow	26.0	
		2. Minimum Outflow	18.2	92.3
		3. Storage	17.4	
		4. Discharge	15.8	
		5. Evaporation	14.8	

(Source : Authors computation, 2011)

The factor defining variables displayed different patterns. The cumulative percentage explanations range from 79.2 to 92.3%. This shows that all the percentages of explanations were highthroughout the 12 months under study. All the reservoir elements provided strong explanations of the variance (Table 1and Fig. 2). The numbers of selected defining factors vary from onemonth to the other. For example, in the month of December, the 10 reservoir elements were reduced to 5 orthogonal factors with explanations on 92.3%. In 4 of the months (February, March, May and June) the 10 elements were reduced to four each with cumulative explanations ranging from 88% to 91%. In all other instances 3 factors were selected as relevant to the explanations (Table 1). The factor scores were used as input into the multiple regressions and stepwise multiple regression models.

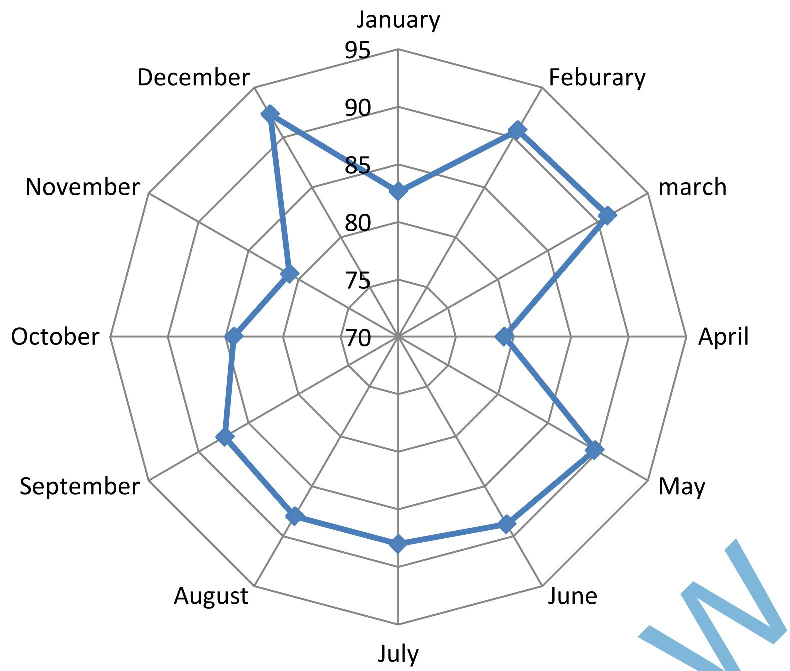


Fig.2 : Monthly Percentage Contribution Of Factor Analysis Cummulative Varaiance Explained By Reservoir Elements

According to Table 2 and Fig. 3 the percentages of explanations of the multiple regression range from 13.4% in April and 98.5% in February, while that of stepwise multiple regression method was a highest of 95.7% in February, while no value was recorded for April. In the case of multiple regression all the percentages of explanation were sufficiently strong with the exception of April, which has the least explanation of 13.4%. The month of April is generally a month of low flow in Jebba when the reservoir is generally at its lowest when it is expected that the reservoir elements will possibly contribute little to power generation.

Table 2 : Percentages of explanations of regression models

S/N	Month	Multiple Regression R^2	Stepwise Regression			Frequencies of entries of Individual Variables into the Regression Equation
			Cumm.% R^2(%)	Reservoir Elements	R^2 of Individual Factors (%)	
1	January	59.3	57.8	Discharge	57.8	1
2	February	98.5	95.7	Peak Inflow	95.7	2
				Minimum Inflow	2.70	
3	March	95.3	87.3	Storage	69.8	2
				Average Outflow	17.5	
4	April	13.4	0.00	Nil	0.00	0
5	May	97.6	95.0	Reservoir Level	95.0	1
6	June	96.9	78.5	Reservoir Level	78.5	1
7	July	89.0	87.1	Discharge	87.1	1
8	August	89.1	87.5	Discharge	87.5	1
9	September	79.7	72.2.	Peak Inflow	72.2	1
10	October	85.8	84.4	Peak Inflow	84.4	1
11	November	54.0	52.0	Discharge	52.0	1
12	December	91.0	55.5	Evaporation	55.5	1

(Source : Authors computation, 2011)

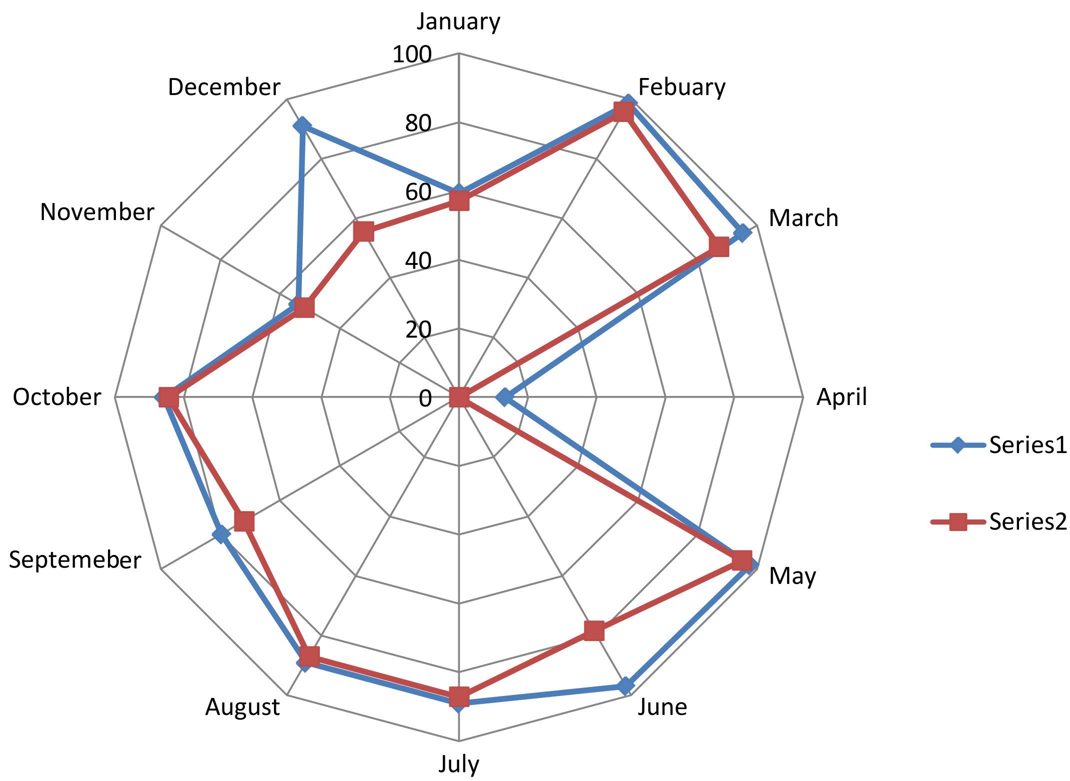


Fig. 3 : Pecentages of explaltions of multiple and stepwise regerssion in Jebba dam

***Note** : Series1=Multiple Regression; Series 2 =Stepwise Regression*

The result also showed that the entry of individual reservoir elements into the stepwise regression equation (Table 3; Fig.4)depicts that reservoir level has the highest frequency of 3 times, while minimum inflow, peak inflow and discharge entered the equation 2 times each, andstorage balance, lake evaporation and average outflowappeared once,while peak outflow, average outflow and minimum outflow made no appearances at all. The dominance of reservoir level suggestsits relevance to power output in the power house. The higher the reservoir level the higher the power generated. The relevancies of the inflow variables also show that it is the major source of water to the reservoir. The negligence of the outflow terms signify that reservoir balance was not really exceeded in such a waythat much water was available for spilling to the downstream. This agrees with the work of Aribisala and Sule (1999) and Salami, (2010) on the downward trend of water inflow in the power dams of Kainji and Jebba.

Table 3 : Frequency of Entries of Factor Defining Variable in the Stepwise Regression Equation.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct.	Nov.	Dec	TOTAL
1.Mini Inflow	0	1	0	0	0	0	0	0	1	0	0	0	2
2.Storage Balance	0	0	1	0	0	0	0	0	0	0	0	0	1
3. Evaporation	0	0	0	0	0	0	0	0	0	0	0	1	1
4.Average Outflow	0	0	1	0	0	0	0	0	0	0	0	0	1
5.Peak Inflow	0	1	0	0	0	0	0	0	0	1	0	0	2
6.Peak Outflow	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Reservoir. Level	0	0	0	0	1	1	1	0	0	0	0	0	3
8. Average Inflow	0	0	0	0	0	0	0	0	0	0	0	0	0
9.Minimum Outflow	0	0	0	0	0	0	0	0	0	0	0	0	0
10. Discharge	1	0	0	0	0	0	0	1	0	0	1	0	2
TOTAL	1	2	2	0	1	1	1	1	1	1	1	1	

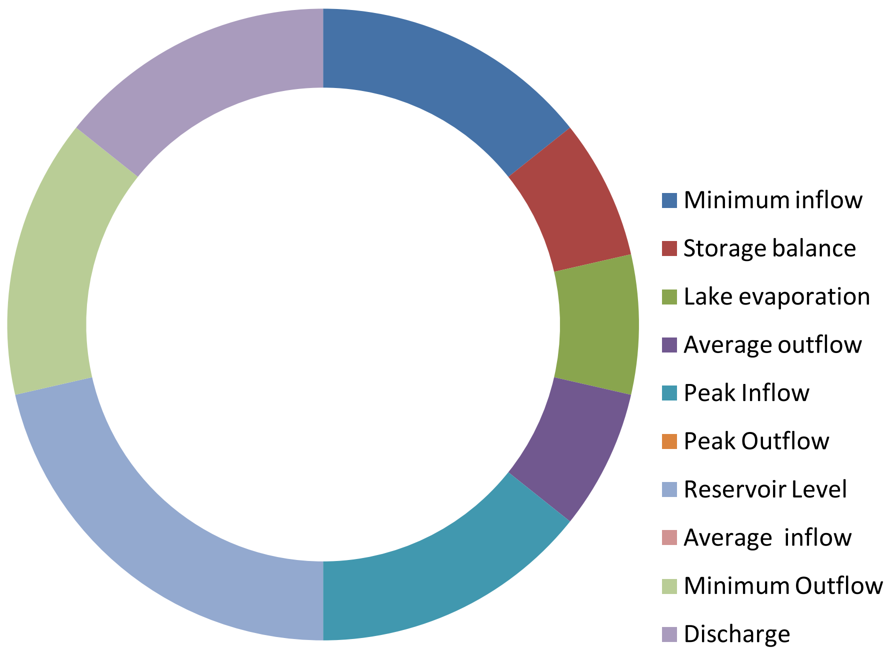
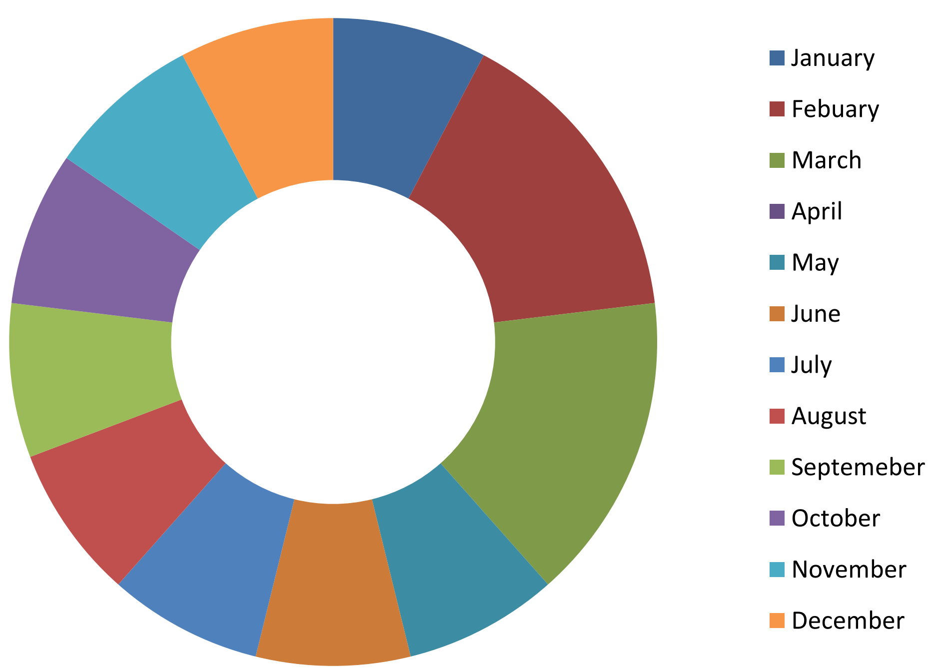


Fig.4 : Frequenecies of Entries of Individual reservoir elements into the stepwise regerssion equation

On the pattern of entries on monthly basis, only the months of February and March have 2 entries while all other with the exception of April had one variable each in the stepwise regression model. This clearly suggests that high level of redundancy exist in the nature of explanations of reservoir elements and power generation. This shows that some elements may sometimes not be needed in monthly power generation (Fig 5).

Fig. 5 : Frequencies of Monthly Entrires of percentages of explanations of stepwise regerssion model into the Stepwies regerssion model



V. Relationships Between Electricity Generation and Reservoir Elements and Power Generation Models in Jebba Dam

The following models (eq. 5-26) are derived from the regression models and can be used to predict monthly electric power generated in the Jebba hydro power dam.

a) January

The result of the multiple regression showed that peak inflow, storage and evaporation explained 59.3% of the variance in the total electricity generated in January. This suggests that 40.7% of power generated in January is due to other factors. Mean in January the Jebba reservoir will be experiencing the black flood.

$$Y_1 \text{Jan} = 151{,}873.50 + 14{,}339.5\text{pkinflow} + 10{,}055\text{storage} + 14644\text{evaporation} \quad \text{......(eq.5)}$$

$$(R^2 = 59.3\%; SE=23{,}155)$$

b) February

In February, the flood water is receding and the reservoir balance is dropping, inflow is getting reduced and little water output is allowed. Hence, minimum inflow, reservoir storage, average output and peak flow accounts for 98.5%. The stepwise analysis that was used as a rank-reduction model was showed that peak inflow and minimum inflow are the dominant factor respectively as these 2 elements explained 98.3%. Hence, prediction of electricity generation in February is better with equation 2.

$$Y_1\text{Feb}=149{,}508.44+7166.98\text{mininflow}+1{,}142.3\text{storage}+1{,}697.8\text{avgoutput}+433{,}446\text{pkinflow}) \quad \text{..... (eq. 6)}$$

$$(R^2=98.5\%; SE=7{,}744)$$

$$Y_2\text{Feb}=149{,}508.44+43{,}445.9\text{pkinflow}+7{,}166.98\text{mininflow} \quad \text{...... (eq.7)}$$

$$(R^2 = 98.3\%; SE=6750.7)$$

c) March

In march 4 factors namely: minimum inflow, storage, average outflow and peak flow predicted 95.3%. In March the water storage is no more influenced by the inflow. The inflow is now reduced as the reservoir is no longer in flood, the storage is now drawn for generation, little outflow is permitted and peak inflow is no longer relevant. The stepwise model reduced the equation to 87.3% with storage and average outflow as the explanatory factors; suggesting that 12.7% of the explanation is due to other factors.

$$Y_1\text{Mar}= 102.252+0.12\text{mininflow} +0.41\text{storage} +0.21\text{avgoutflow}- 0.07\text{pkinflow} \quad \text{....(eq.8)}$$

$$(R^2 = (95.3\%; SE = 15{,}052)$$

$$Y_2\text{Mar} = 102.252 + 0.411\text{storage} + 0.21\text{avgoutflow} \quad \text{...(eq.9)}$$

$$(R^2 = 87.3\%; SE = 20{,}233)$$

d) April

In April the reservoir element had a weak prediction of the electricity generation. Three elements namely: peak outflow, storage and average inflow predicted 13.4% of the variance in the equation. This clearly shows that reservoir elements are poor predictor of power generation in April. This expected in view of the fact that, April is generally a period of low. The inflow variables are generally weak.

$$Y_1\text{Apr}=150{,}643.89+13{,}272.15\text{pkoutflow}+5{,}846.16\text{storage}+8{,}409.06\text{avginflow} \quad \text{.... (eq.10)}$$

$$(R^2 =13.4\%; SE = 53{,}887)$$

e) May

May marks the beginning of the rainy season around the Jebba area; hence some forms of local rains are received locally. Peak inflow is having a weak contribution into the reservoir, the level of the lake is been affected, evaporation is also an issue, it is higher than rainfall, but yet some amount of water still have to be spilled, therefore the outflows still plays a role in reservoir operations. These 3 elements account for 98.8% of the energy generated in the Jebba dam. Indeed, the reduce model showed that reservoir level alone account for 95.1% of power generation.

$$Y_1\text{May}=101.908\text{-}029\text{pkinflow}+0.599\text{level}+0.059\text{avgoutflow}+0.071\text{evaporation.} \quad \text{..... (eq.11)}$$

$$(R^2 = 98.8\%; SE= 13516)$$

$$Y_2\text{May} = 101.908 + 0.599\text{level} \quad \text{..... (eq.12)}$$

$$(R^2 = 95.1\%, SE = 14{,}561)$$

f) June

The white flood is already creeping in at the reservoir in June in view of the rainfall in some parts of the basin in northern Nigeria. Hence, inflow is now making an appearance, the output values of average outflow and discharge have to be controlled in other to allow the reservoir to fill. In June, minimum outflow, average outflow, reservoir level and discharge explained 96.9% of the total energy generated.

$$Y_1\text{Jun} = 101.834 + 0.151\text{mininflow} – 216\text{avgoutflow} + 0.613\text{level} – 0.135\text{discarge} \quad \text{.... (eq.13)}$$

$$(R^2 = 96.9\%, SE = 0.172)$$

$$Y_2\text{Jun} = 101.834 + 0.613\text{level} \quad \text{.... (eq.14)}$$

$$(R^2 = 78.5\%, SE = 0.34)$$

g) July

In July, the reservoir is also experiencing some level of influence of the white flood. The role of minimum inflow and reservoir level are more important. The outflow terms such as discharge are not contributing positively to power generation.The result of reservoir level is still a dominant variable in electricity generation as it account for 87.5% of power generation in July.

$$Y_1\text{Jul} = 154397.44 + 1006.24\text{mininflow} –3761.172\text{discharge} + 28614.9\text{level} \quad \text{.... (eq.15)}$$

$$(R^2 = 89.1\%; SE= 12{,}770)$$

$$Y_2\text{Jul} = 154397 + 28614.92\text{level} \quad \text{.... (eq.16)}$$

$$(R^2 = 87.5\%; SE = 11{,}567)$$

h) August

In August the reservoir is getting filled up and some spillage have to be done in the reservoir and this account for the outflow terms of average outflow and discharge in other to protect the reservoir. Average outflow, storage and discharge account for 89.1% of the variance. The result of the stepwise regression shows that discharge explains 87.5% of the variance.

Y_1Aug = 154,397.44+1,006.24avgoutflow -3,761.17storage +28,614.9discharge .... (eq.17)

(R^2 = 89.1%; SE=12,770)

Y_2Aug = 154,397.44 + 28,614.9discharge) ....(eq.18)

(R^2 = 87.5%; SE = 11,567)

i) September

September is the supposed peak of the white flood in Jebba reservoir. Minimum inflow is dominant factor in the reservoir operation in September. Average outflow and level are weak contribution at this time. This is expected because the reservoir is getting filled up and the river is in flood. The inflow term has the highest contribution of 72.2% to the variance in the equation.

Y_1Sep = 135,306.22 + 28,935.17mininflow - 8,036.28avgout flow – 4,718.74level ..... (eq.19)

(R^2 = 79.7%; SE = 19,413)

Y_2Sep = 135,306.22 + 289,335.17mininflow…….. (eq.20)

(R^2 = 72.2%; SE = 19,194.9)

j) October

The inflow terms are the most dominant, the river in Nigeria is now in flood as every area of Nigeria is now receiving rainfall. Peak inflow, storage and average inflow are very important to the explanation in the equation. The stepwise regression showed that peak inflow alone explained 84.4% of the variance.

Y_1Oct=161,752.89+39,670.67pkinflow+627.4storge+5,147avginflow .... (eq.21)

(R^2=85.8%; SE=20,583.1)

Y_2Oct = 161,752.89 +39,670.6pkinfow ..... (eq. 22)

(R^2=84.4%; SE = 18258.0)

k) November

The 'black flood' is already seeping in. average inflow and peak inflow is still dominant. Discharge is also very significant. These 3 elements contributed 54% explanation, while discharge also explains 51.6% explanation in the variance. The dominance of discharge is because at this time water is spilled.

Y_1Nov=146,223.56+5,847avginflow.12+3,002pkinflow+30 716discharge ……. (23)

(R^2=54%; SE = 38,691)

Y_2Nov=146,223.56+3,0716discharge …….. (24)

(R^2=51.6%; SE= 31,796)

l) December

December marks the peak of 'black flood' and therefore one expect all the output terms to be most dominant. These are: peak outflow, minimum outflow, storage, discharge and evaporation all this explained 91% of the variance in the equation. This expected in view of the flood, the output terms became dominant since the reservoir have to be protected in view of the drawdown level is still high since the reservoir is just coming out of the 'white flood' of June to October. Hence, by November and December, the lake is still filled and the reservoir would have to be spilled. The high rate of evaporation is because of the high potential evaporation in Jebba.

Y_1Dec=302,460.67+133,615.69pkoutflow+114,877.49minoutput+203,774.95storage+87.610.17discharge+353,722.86evaporation ….. (25)

(R^2=91.1%; SE=231,078.96)

Y_2Dec= 302,460.67+353,722.86evaporation …… (eq.26)

(R^2=55.5%; SE=338,524)

The above shows that reservoir elements played significant role in the explanation of electricity generation in 11 months except in the month of April when weak explanations were recorded. The results of the stepwise regression which was used as a reduce model shows that February andMarch have the highest numbers of factors (2 each). All others have 1 each with the exception of April whenno factorentered into the equation, Also, reservoir level has the highest entry (3 times) and peak outflow and minimum outflow have no entry at all.

V. Conclusion and Policy Implication

A causal relationship exists between electricity generation and power generation and reservoir elements in Jebba dam. This is expected since turbine operations depend on the reservoir management. If efficiency is expected in hydropower dams, the hydrologist must have detail knowledge about the interactions of the reservoir elements as guide to dam operation.

This research showed that fewfactors are most relevant to electricity generation. The level of relevance of these elements varies from months to month. However, during low flows the reservoir elements have negligible roles in power generation. Also in the flood seasons, the output termsare dominant in dam operations in other prevent dam failure and wastage of energy. In the off-peak runoff season the inflow attributes are dominant. The reservoir operator must therefore be familiar with all these details for efficient performance. There is a need for further study of the existence of redundancy in the performance of reservoir elements in Jebba dam.The power generation models derived in this study could be relevant in predicting power generation in Jebba and will provide a leeway in design an efficient reservoir rules.

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