

Transient Water Discharge Effect On Hydropower Stations

BY

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Abstract

In Egypt, hydropower is considered as a by-product as irrigation demand is given the first and foremost priority over the other water uses. However, determination of the day-to-day generated hydropower at hydraulic structures is essential because it represents about 22% of the total electric power. This shows the importance of identifying the characteristic equation for each hydraulic structure in Egypt to estimate the electric power generated out of the available amount of water released. This study is based on the point of view of the Ministry of Water Resources and Irrigation. However, it considers the data of the Ministry of Electricity. Three trials for identify the characteristic equations to estimate the hydropower generation from hydraulic structures such as barrages were considered. These different trials are based on analyzing the historical data of discharge and water level upstream and downstream the barrage taking into account three different data handling alternatives in the period between (1991 – 2000). In the general equation relating the hydropower with the discharge and net head (difference of water level upstream and downstream barrage) all the generators and turbines' parameters were considered as one factor. This factor was based on the actual annual average efficiency of the electrical system that was obtained from the Ministry of Electricity annual reports. The analysis showed that the best characteristic equation that can represent the generation of hydropower based on either the discharge or water level head is a linear degree. The actual collected data during the indicated period were used for estimating the coefficients of these equations. Also, the calculated Hydropower using the characteristic equation was compared with the measured value for each year. The results showed that the calculated values are very close to the measured ones. This concludes that these linear equations may be used in the future for estimating the best values of the Hydropower that can be generated from these barrages according to the pre-estimated requirement of the discharge and estimated water head.

Introduction:

Power is a very important infrastructure of the overall development of a nation. It is the tool to forge the economic growth of a country. There has been, therefore, an ever increasing need for more and more power generation recently in all the countries of the world. In Egypt, hydropower is considered as a by-product as

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irrigation demand is given the first and foremost priority over the other water uses. However, determination of the day-to-day generated hydropower at hydraulic structures is essential because it represents about 22% of the total electric power. Running costs of the hydropower installation are very low as compared to the thermal stations or the nuclear power stations and the hydraulic turbines can be put off and on in matter of minutes.

Aim of Work:

Determination of the day to day generated hydraulic power at the large hydraulic structures along river Nile is needed. Therefore, the aim of this study is to estimate the electrical generated hydropower from the released predetermined amount of water according to the irrigation demands in Egypt; this will be achieved through the following steps:

1. Develop characteristic curves for the generated electric power related to discharge at different hydraulic structures. Knowing the irrigation demand will help the engineers in the Ministry of Electricity to schedule the maintenance period as well as the schedule of operation in each hydroelectric station.
2. Prediction of generation hydropower regarding the characteristic equation for every station, future discharges and turbines capacity.

Types of Data:

Water Level Upstream and Downstream Barrages

Water level daily measurements upstream and downstream the four hydraulic structures are recorded by the responsible technicians at these locations in a special form. The author collected these data from the records in Aswan. The complete records for AHD electric station was obtained for the period (1991 – 2000).

Water Discharge

There are two categories of recorded values for water discharge at every hydraulic structure. The first is the turbine discharge, while the second named spillway discharge in million m^3/day ($M.m^3/day$). At AHD the spillway discharge depends on the requirements of irrigation and navigation. If the amount of water requirement is more than the capacity of the turbines, the excess water passes through the spillway.

Efficiency Factor of Power Stations

One of the data required to identify the characteristic equation for each station is the actual efficiency factor. These records were obtained from the annual reports of Ministry of Electricity and Energy. These factors ranged between (84.9%) and (85.6%) at AHD.

Methodology

Generated Power Estimation

The proposed method depends on a huge number of data such as (water level upstream and downstream each station, water discharge and efficiency). The main objective of this study is to estimate a characteristic equation to identify the generation of hydropower for every studied hydropower station. In the general equation relating the hydropower with the discharge and net water head all the generators and turbines' parameters were considered as one factor. This factor was based on the actual annual efficiency of the electrical system that was obtained from the Ministry of Electricity annual reports.

General Equation of Hydro-Power

The generated electric power output of a hydroelectric plant is given by the equation:

$$P(kW) = \frac{\eta \gamma Q (m^3/s) H (m)}{1000} \quad (1)$$

Where

P = generator output in (kW)

Q = Water flow through the turbine (Discharge) in $.m^3/sec$.

H = net head of water (m) (the difference in water level between upstream and downstream of the turbine)

η = Station Efficiency

To calculate the available energy that can be generated within 24 hours in (GWh), the following form will be used:

$$E (GWh) = \frac{P (kW)}{1000 * 1000} * (24) \quad (2)$$

Estimation of characteristic Equation

Based on the data of the period from (1996 – 2000), for every hydropower station, characteristic curve is estimated and its equation is developed. A regression for the collected data between estimated hydropower and water discharge has been carried out. Since water head varies usually within a narrow range, the average water head is considered in calculating the generated electrical power. Three values of average water head were considered. The first takes into account average monthly water head, the second takes the average over one year, and the third takes the average over the total data collection period.

Average Net Water Head

These values of net water head were taken to estimate the generated power at any station. While the actual data (daily net water head) is the principal in comparison the results. We used the calculated average net water head based on the month, the year, or all data. That is mean that in 48 month (four years) there are 48 different values for monthly average H, 4 different values for yearly average H in the four years, and one value for average H according to all data. Power has been calculated based on these three states for every year and were compared with power calculation based on actual (daily) net water head for the same year. If the result is similar to daily net water head (actual H)

this means that the variance through the month is low. Also if the result is similar to the value of power based on annual average net water head, this means that the variance in H isn't big through the year and we can make the comparison between actual H and average H.

Equation for Every Year

The main objective for the author is to find one equation or more to represent the station to help the operator in the station in varying conditions of water irrigation. In this alternative the author creates one equation for every year from its actual data and applied this equation on data of other years, i.e, equation of year 1999/2000 was applied on data of year 1998/1999, data of year 1997/1998, and data of year 1996/1997. These steps have been repeated repeat on every year individually. If the equation for one year represents successfully the data for another year we conclude that this equation is the characteristic equation for the station. See figure (1).

General Equation of all data

In the third trial, the whole collected data for the period (1996 to 2000) were used for generation one equation. This equation is applied with data of every year at the same station, i.e, the equation that was created from all data is applied on data of year 1999/2000 with equations of other years (1998/1999, 1997/1998, 1996/1997). To test the accuracy of this equation, it was applied for the data of each year individually with equations of other years. The results of this trial are very good, as indicated in the figure (2).

All these trials are applied on data at AHD station, from the results we find the third trial gives the best values at AHD station. From these results it was concluded that general equation from all data is used as a characteristic equation represents AHD station for all years.

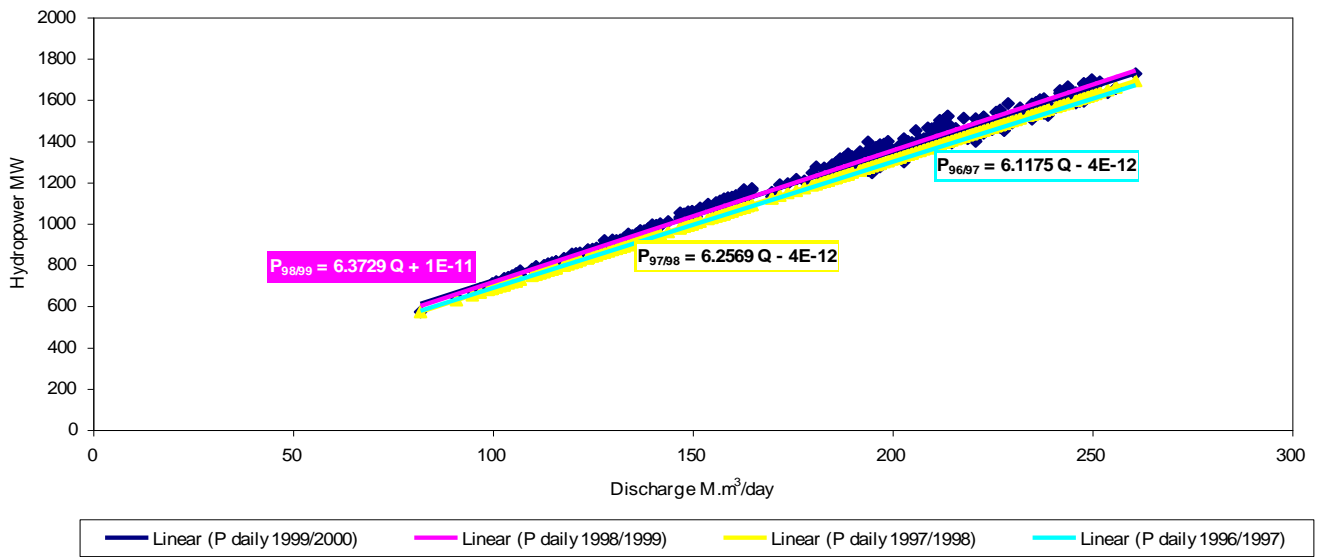


Fig. (1), Second trial (Equation for Every Year) at AHD Year 1999/2000

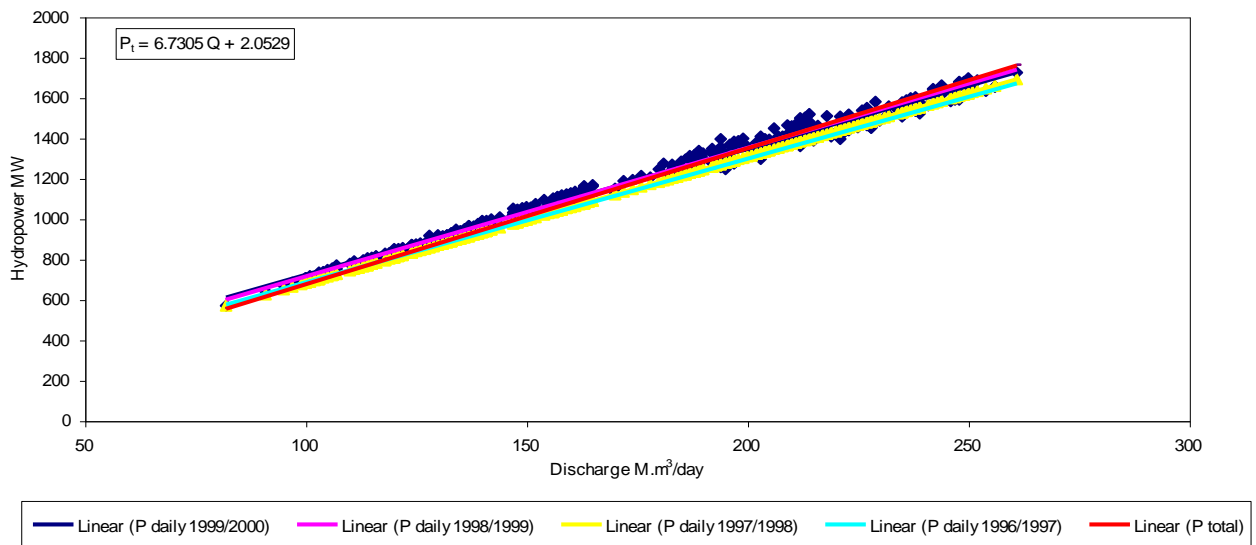


Fig.(2), Third trial (general equation for all data) at AHD Station year 1999/2000

Discussion of Results

Characteristic Curve based on (P & Q)

All trials are applied on data that are related to AHD Station. The results of all trials are compared with the actual data at every station. From the comparison it is concluded that the third trial equation (general equation for all data) gives the best curve and best equation. This equation has been applied on actual data of every station to get the hydropower value of the calculated power was found similar to value of actual power. The type of equation is a linear the data during the period from (1996 / 1997 to 1999 / 2000) have been used for the estimation of this equation. Different coefficients in the equation of every year are indicated in the table (5.1). Fig. (3) represents data of the year, while fig. (4) represents the characteristic equation for AHD.

Table (1), Coefficients of different Equations for every Year based on (P & Q) for generation of Hydropower at AHD.

Year	A	B
1999 / 2000	6.2449	97.122
1998 / 1999	6.3729	76.751
1997 / 1998	6.2569	57.181
1996 / 1997	6.1175	73.832

The characteristic Equation, which represents the ideal relation between generated hydropower and discharge for the AHD station is

$$P_{ch} = 6.7305 * Q + 2.0592 \quad (5.1)$$

A comparison between the actual values of hydropower and calculated values based on the developed curve has been done and the results are shown in table (5.2).

Table (2), Comparison between Estimated and Actual Values of generated hydropower at AHD

year	Act. val.	Est. val.1	Dis. fact	Est. val.2	Dis. fact	Est. val.3	Dis. fact
96/97	8738.0	9432.83	1.08	8310.34	0.95	8937.94	1.02
97/98	8949.0	8901.86	1.00	8383.94	0.93	9033.40	1.00
98/99	11450.	11702.93	1.02	10645.5	0.92	11449.9	0.99
99/00	10889.	10769.27	0.99	9553.88	0.87	10509.3	0.97

From table (5.2) it is noted that the difference between estimated values and measured values of hydropower is ranged between -3 to 2 %. This indicates the estimated hydropower is very close to the measured values.

Water discharge at the turbines from hour to hour that explain in detail the operation method isn't available. From available (daily) data, it is noted that there are fluctuation occurs in water discharge on the turbines, i, e, water discharge in year 2000 ranged from 126 M.m³/day in 7 January to 103 M.m³/day in 8 January. Where the monthly variation in year 1997 ranged from 272 M.m³/day in July to

51 M.m³/day in December. This fluctuation affects on operation quality of turbines. If we regulate the operation period and amount of water discharge according to policy of water discharge and capacity of turbines it will be very useful to increase the value of power accordingly.

Relation between P & H

From daily water levels and calculations of net water head it is found at AHD station, daily net head ranged between 65.85; 68.95 m. The average value all over the month exceeds the daily value, it is 67.68 m, while all over the year the value of H exceeds the average monthly value, where it is 70.68 m. Therefore, it is concluded that generally the operation of the hydropower station at AHD is uniform all over year even with the flood year. Table (3) indicates the calculated hydropower based on the average yearly net water head at AHD.

Table (3), Calculated Power with Average Yearly Net Water Head at AHD Station, July, 1999/2000.

Date	Average Yearly Net water Head	Discharge	Power
day	m	M.m³/day	MW
1	70.68	204	1393.1
2	70.68	228	1557.0
3	70.68	216	1475.1
4	70.68	227	1550.2
5	70.68	220	1502.4
6	70.68	217	1481.9
7	70.68	219	1495.6
8	70.68	221	1509.2
9	70.68	197	1345.3
10	70.68	212	1447.7
11	70.68	225	1536.5
12	70.68	228	1557.0
13	70.68	239	1632.1
14	70.68	232	1584.3
15	70.68	228	1557.0
16	70.68	203	1386.3
17	70.68	228	1557.0
18	70.68	225	1536.5
19	70.68	227	1550.2
20	70.68	222	1516.0
21	70.68	203	1386.3
22	70.68	227	1550.2
23	70.68	194	1324.8
24	70.68	228	1557.0
25	70.68	226	1543.4
26	70.68	228	1557.0
27	70.68	228	1557.0
28	70.68	221	1509.2
29	70.68	226	1543.4
30	70.68	195	1331.7
31	70.68	230	1570.7

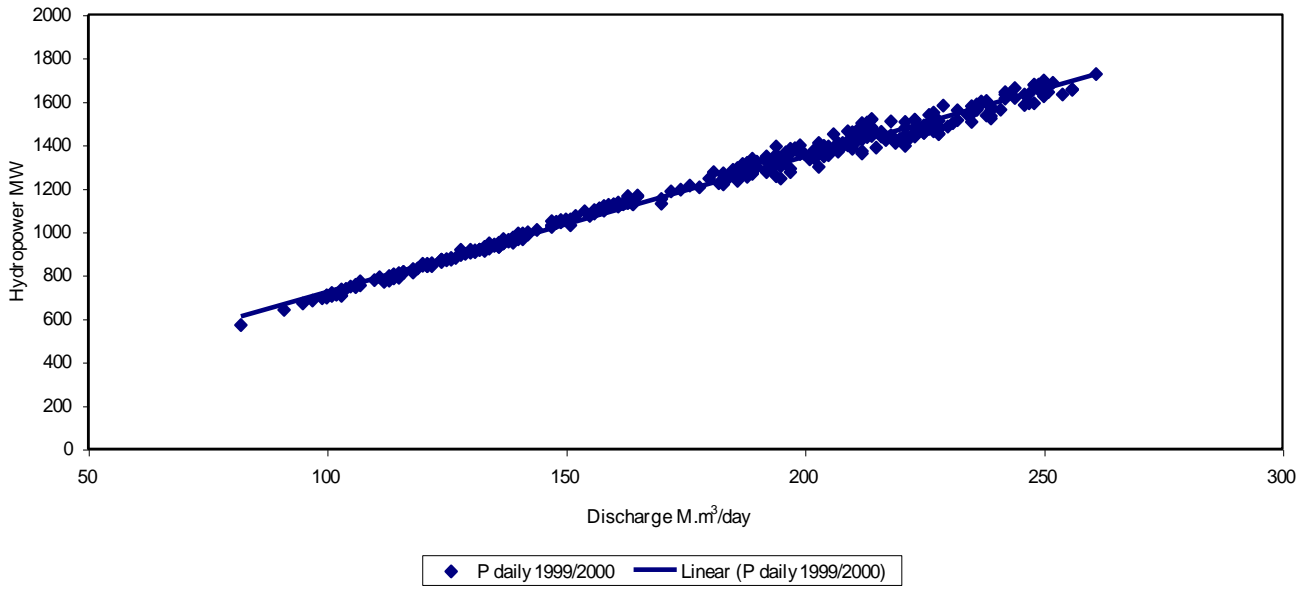


Fig. 3), Actual Data for year 1999/2000 at AHD Station

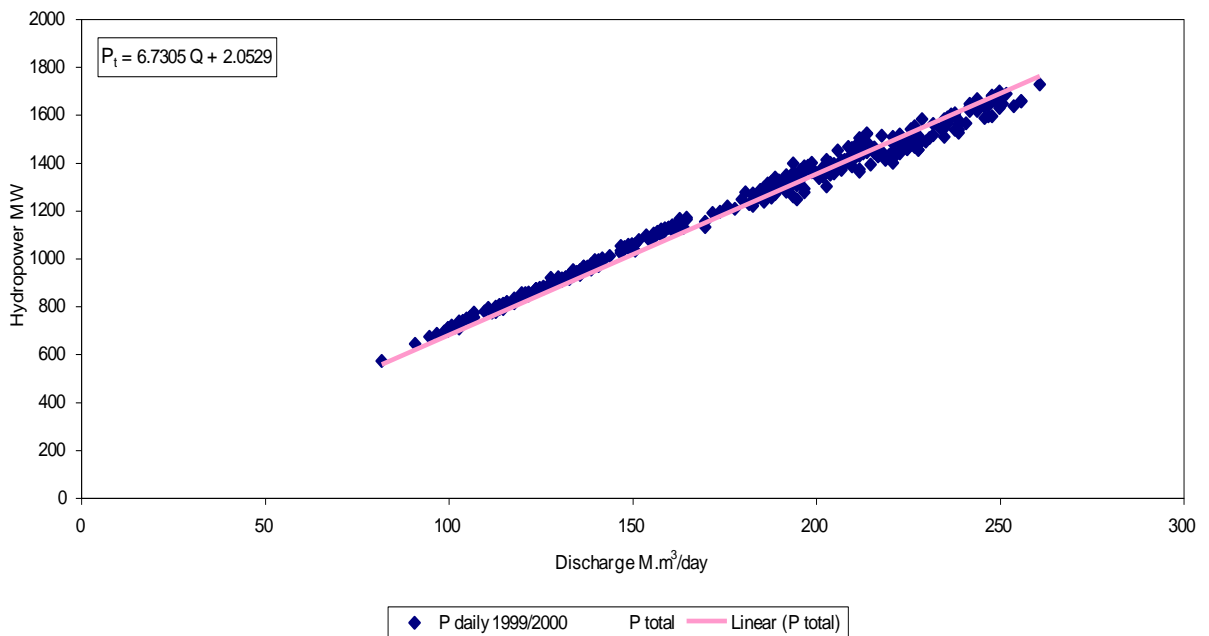


Fig. (4), Characteristic Curve represent Data of Year 1999/2000 at AHD Station

Conclusions

1. Generally the operation of the hydropower station at AHD is uniform all over year even with the flood year.
2. The best characteristic equation that represents the generation of hydropower based on the discharge is a linear type.
3. The characteristic equation can be used for the estimation and prediction of hydropower values from AHD station in the futures.
4. Third trial gives the best result with AHD but second trial may give the best results at anther hydropower station.

Recommendations

- 1- The different trials have to be applied at all hydropower stations on the river Nile.
- 2- The hydropower power at different stations have to be used as a base load with regulated water discharges at turbines.

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