CHARACTERISTIC EQUATIONS FOR HYDROPOWER STATIONS OF MAIN BARRAGES IN EGYPT

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ABSTRACT

Determination of the day-to-day generated hydropower at hydraulic structures is essential because it represents about 22% of the total electric power in Egypt. 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. Three trials for identifying the characteristic equations to estimate the generated hydropower from main Barrages were considered. These different trials are based on analyzing the historical data of discharge and water level upstream and downstream the Barrages taking into account three different alternatives in the period (1991 – 2000). In the general equation relating the hydropower with the discharge and net head (difference of water level upstream and downstream Barrages); 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 annual reports of the Ministry of Electricity. The analysis showed that the best characteristic equation represents the generated hydropower based on either water discharge or water head is the linear equation. The actual data during the indicated period were used for estimating the coefficients of these equations. Also, the estimated Hydropower using the characteristic equation was compared to the measured value for each year. The results showed that the estimated values were very close to the measured ones. This concludes that these linear equations can be used in the future for estimating and predicting the best values of the generated Hydropower from these Barrages according to the pre-estimated values of the discharge and the water head.

Keywords: Hydropower stations, Barrages, characteristic equation.

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 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

1- Water Level Upstream and Downstream Barrages

Water level daily measurements upstream and downstream the four hydraulic structures were 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).

2- 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 mainly 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.

3- 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

1- 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.

2- General Equation of Hydro-Power

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

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

in which:

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
γ = specific weight of water (N/m^3)

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

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

3- Estimation of characteristic Equation

Based on the data of the period from (1996 – 2000), for every hydropower station, characteristic curve was estimated and its equation was developed. A regression for the collected data between estimated hydropower and water discharge was 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.

4- 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 with 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 was 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 is not big enough through the year and we can make the comparison between actual H and average H.

5- Equation for Every Year

The main objective of this research 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 research 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 were repeated 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 (refer to figure (1)).

6- 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 was applied with data of every year at the same station, i.e., the equation that was created from all data was 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 figure (2).

All these trials were applied on data at AHD station. From the results, one found the third trial gave the best values at AHD station. From these results, it was concluded that general equation from all data was used as a characteristic equation representing AHD station for all years.

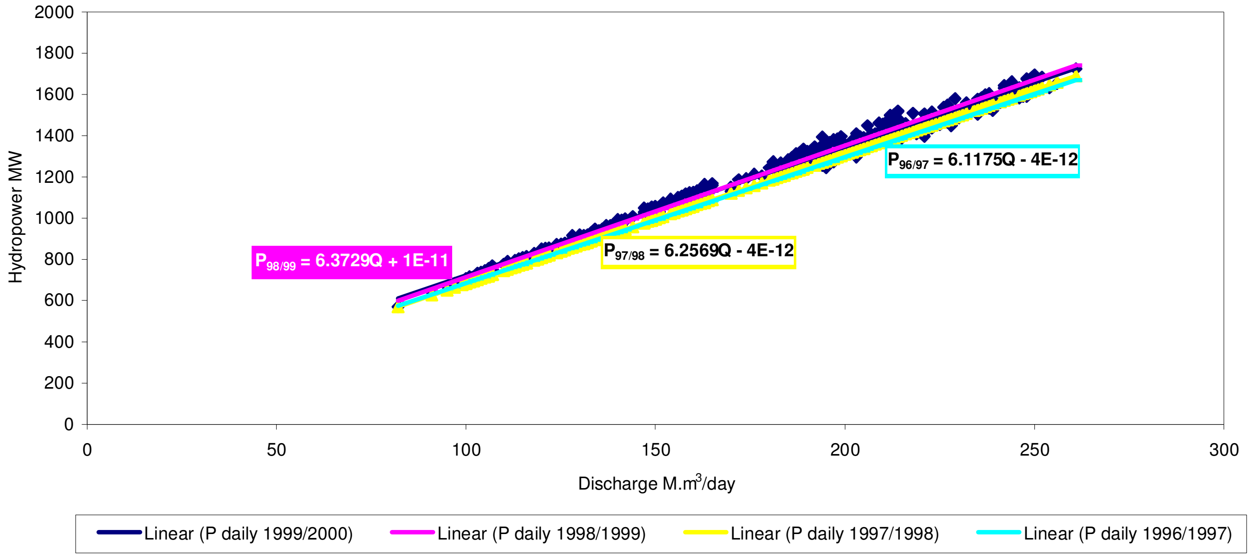

Fig. (1), Second trial (Equation for Every Year) at AHD Year 1999/2000

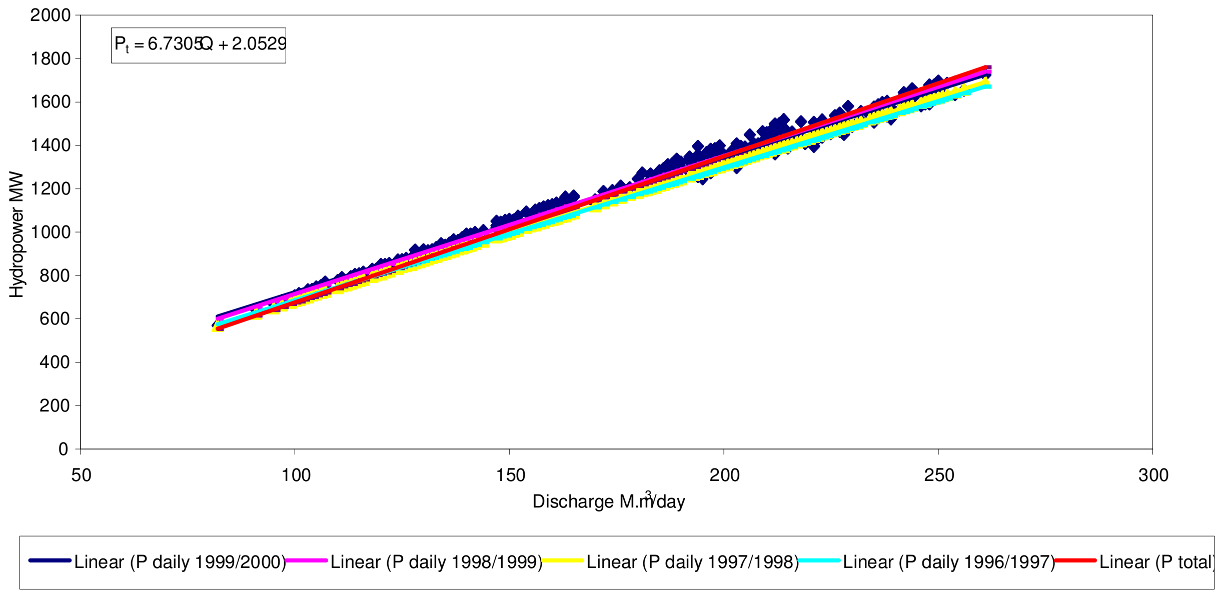

Fig.(2), Third trial (general equation for all data) at AHD Station year 1999/2000

DISCUSSION OF RESULTS

Characteristic Curve based on (P & Q)

All trials were applied on data that are related to AHD Station. The results of all trials were compared with the actual data at every station. From the comparison it was concluded that the third trial equation (general equation for all data) gave the best curve and best equation. This equation applied on actual data of every station to get the hydropower value of the calculated power which was found similar to the value of actual power. The type of the equation was linear using the data during the period from (1996 / 1997 to 1999 / 2000) which was used for the estimation of this equation. Different coefficients in the equation of every year were indicated and shown in table (1). Figure (3) represents data of the year, while figure (4) represents the characteristic equation for AHD.

Table (1): Coefficients of different Equations for every Year based on (P&Q) for generated 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

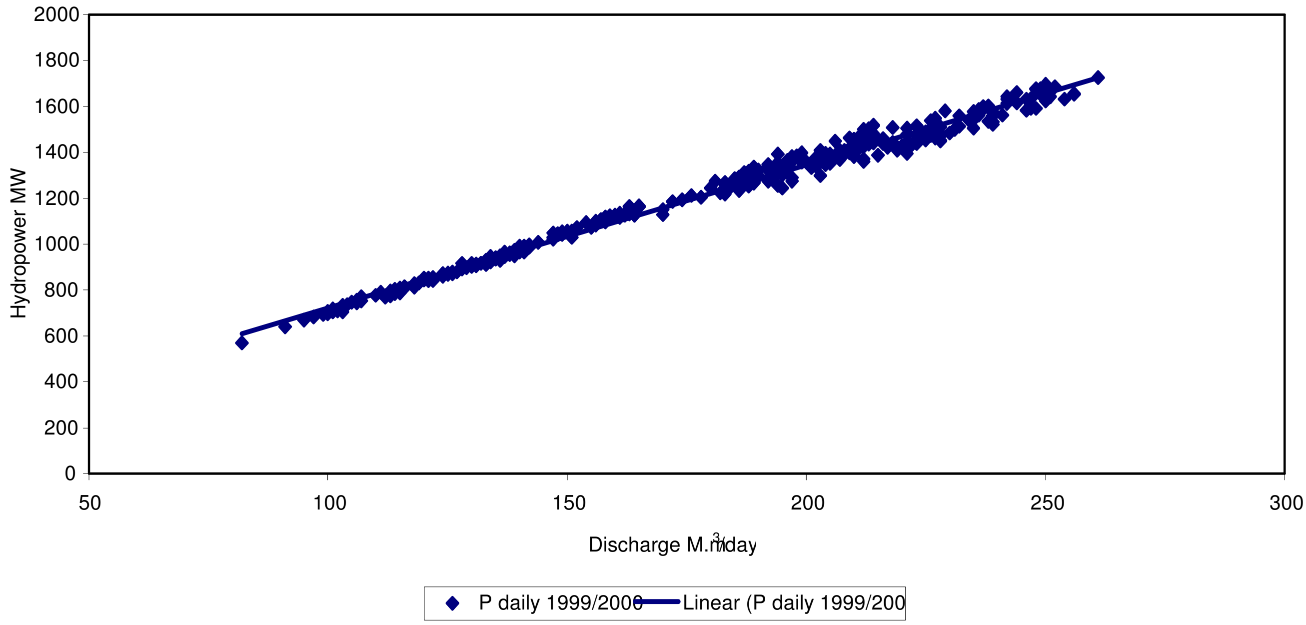

Fig.3), Acutual Data for year 1999/2000 at AHD Station

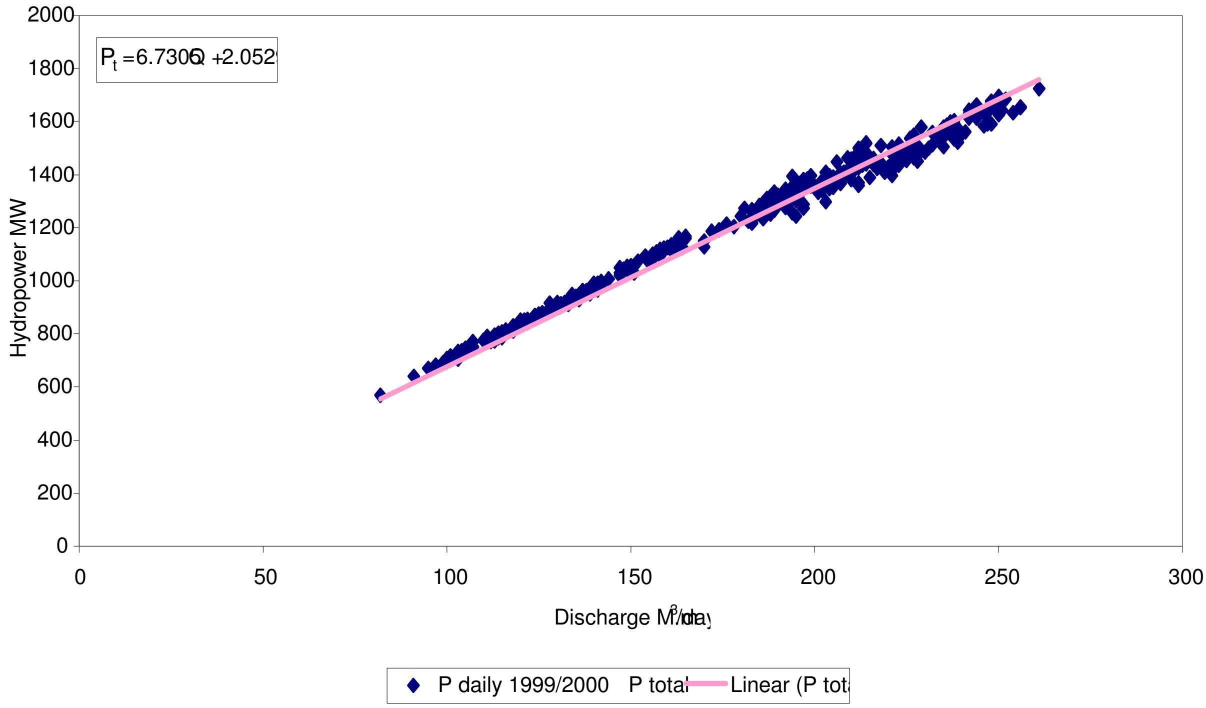

Fig. (4), Charactristic Curve represent Data of Year 1999/2000 at AHD Station

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

$$P_{ch} = 6.7305 * Q + 2.0592 \quad (1)$$

A comparison between the actual values of hydropower and calculated values based on the developed curve was done and the results are shown in table (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	9432.83	1.08	8310.34	0.95	8937.94	1.02
97/98	8949	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 (2) it is noted that the difference between estimated values and measured values of hydropower is ranged between -3 to 2 %. This indicates that 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 is not 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 $M.m^3$/day in 7 January to 103 $M.m^3$/day in 8 January. Where the monthly variation in year 1997 ranged from 272 $M.m^3$/day in July to 51 $M.m^3$/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.

Relationship between P & H

From daily water levels and calculations of net water head it was found that at AHD station, the 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.

CONCLUSIONS

From the above, the following points can be concluded:

1. Generally the operation of the hydropower station at AHD is uniform all over the year even during the flood year.

2. The best characteristic equation that represents the generated hydropower based on water discharge is the linear equation.

3. The characteristic equation can be used for the estimation and prediction of hydropower values from AHD station in the future.

4. The third trial gives the best results with AHD but the second trial gives the best results at the other hydropower stations.

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

Date day	Average Yearly Net water Head m	Discharge M.m^3/day	Power 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

RECOMMENDATIONS

1. The different trials have to be applied at all hydropower stations along the river Nile.

2. The estimated hydropower at different stations has to be used as a base load with regulated water discharges at turbines.

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