Optimization of mode of operations of hydropower stations with reservoir

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Abstract: Optimization of work of electric station with reservoirs is even more difficult task. The main criterion of optimization of energy mode of reservoirs is to maximize energy production in that period of year while there is a shortage of water. For instance, Kayrakum hydroelectric station, which is the only hydroelectric station of the most developed northern region of the republic this period, continues 6-7 months.

Keywords: Optimization, Hydropower, Kayrakum reservoir

1. INTRODUCTION

What can be the role of reservoir here? It seems that this task is easy. According to accepted point of view the more works reservoir the more water will go through turbine and as a result hydroelectric station will produce more energy. Then, the most optimal mode should be such at which reservoir will be filled up to the greatest possible mode to the beginning of considered period and is completely worked at the end.

2. MODELS FOR OPTIMIZATION

Let’s consider two variation of mode of hydroelectric station work without any function of reservoir (on transit flow). Appropriate to this variation the work of energy on hydroelectric station will be equal:

\[ \mathcal{E}_1 = 9.81 \cdot \eta \cdot Q_0 \cdot H_1 \cdot T \cdot 24 \]  

(1)

Q_0-the transit charge through reservoir and hydroelectric station provided the tributary of the river, \( H_1 = \Delta \text{max} \text{ upp.b.} - \Delta \text{low. b.} \) pressure on hydroelectric station, T-Duration considered period in day.

In second variation reservoir in regular intervals works for the considered period up to a mark \( \Delta \text{ upp.b.} \). Having accepted that the area of water s mirrors in reservoir at all its level is equal \( S \) (m²) we consider that in this variation the additional volume of water passed through turbines of hydroelectric station is equal:

\[ V_{\text{add}} = S(\nabla_{\text{max} \text{ upp b.}} - \nabla_{\text{upp b.}}) \]  

(2)

and additional average consumption for entire period:

\[ Q_{\text{add}} = \frac{V_{\text{add}}}{t} = \frac{S(\nabla_{\text{max upp b.}} - \nabla_{\text{upp b.}})}{T \cdot 86400} \]  

(3)

Having accepted with sufficient for estimated accounts mark of tail-water in all cases constant, \( \Delta \text{low. b.} \) the equation (3) we write:

\[ Q_{\text{add}} = \frac{S(H_1 - H_2)}{86400 \cdot T} \]  

(4)

Where: \( H_2=\Delta \text{low. b.} - \Delta \text{low. b.} \) - pressure on hydroelectric station, at the end of the work of reservoir.

In evenly work of reservoir it may be accepted that in second variation the hydroelectric station all the time worked with average pressure:

\[ H_{\text{aver}} = \frac{H_1 + H_2}{2} \]  

(5)

And its energy production will be equal to:

\[ \mathcal{E}_2 = 9.81 \cdot \eta \cdot (Q_0 + Q_{\text{add}})H_{\text{aver}} \cdot T \cdot 24 = \]

\[ = 9.81 \cdot \eta (Q_0 + \frac{S(H_1 - H_2)}{86400T}) \frac{H_1 + H_2}{2} \cdot T \cdot 24 \]  

(6)

With consideration \( \mathcal{E}=9.81 \eta QHt \)

Where \( \mathcal{E} \)-energy (kWh), \( \eta \)-efficiency, \( Q \)-water consumption (m³/sek), \( H \)-pressure (m), \( t \)-time (h) and (6) condition at which the work of reservoir brings to additional effect can be written as:
As a result of elementary transformation from equation (7) we can get two following criterion:

\[
\frac{\eta}{T} = 9.81 \eta \left( \frac{Q_o + \frac{S(H_1 + H_2)}{86400 T}}{2} H_1 + H_2 \right) \frac{T}{24} \geq 1 \quad (7)
\]

\[
T \leq \frac{S(H_1 + H_2)}{86400 Q_o} \quad \text{and} \quad Q_o \leq \frac{S(H_1 + H_2)}{86400 T} \quad (8)
\]

Kayrakkum hydroelectric station with reservoir has following main parameters and can be served as an example.

\[
S = 200 \text{ km}^2; \quad H_1 = H_{\text{max}} = V_{\text{max}}^{\text{up.b.}} - V_{\text{low.b.}} = 347.5-327.5 = 20 \text{ m}; \quad 0 \leq Q_o \leq 900 \text{ m}^3/\text{s}; \quad Q_{\text{av. long stand}} = 600 \text{ m}^3/\text{s}.
\]

The appropriate calculation at formulas (7) and (8) are given in the tables 1,2,3. They show that for really having a place for Kayrakkum hydroelectric station of range of change (400≤Q≤900) of the average consumption and pressures of work (9≤H≤20) the efficiency of use of reservoir takes place only at it fully draining during no more than 70-120 that is much less shortage of the electric power of the autumn-winter period, which is seven months (October- April).

Thus for representing practical interests of the periods of time (T>180) the efficiency of work of reservoir for real pressures is provided only at average charges 300-400m³ that is essentially smaller valid.

Concrete sizes of losses of production of the electric power at work of reservoir shows Fig. 1. At usual for today's practice H₂ ≈10 m and T =180 days they comprise 10% or in absolute meanings 70-80mln.kWhour a year.

The given analysis even in view of the made simplifications show that the mode of operations of Kayrakkum reservoir accepted today in practice, is not optimum from the point of view of power. The loss of energy is obvious during such mode. Moreover, it is not effective for irrigation because a big work of reservoir would result in additional expenses of energy at pumping station.

3. OPTIMIZATION OF KAYRACKUM HYDROPOWER

As an example we consider the concrete task of optimization of Kayrakkum hydropower station at Syrdarya River in Tajikistan. Its capacity is 126 MWt; the volume of reservoir is 4.6km³ and useful 2.6km³. The reservoir of Kayrakkum hydro electric station is the biggest for all northern zone of republic hydro electric station, which is isolated from its basic energy system and carries out seasonal regulation of flow in the most intense river pool of Aral Sea in the interests of following republics: Kazakhstan, Turkmenistan and Uzbekistan. The additional need in water for these republics in vegetation period comprises 2.2km³.

For the defining of national and regional interests we consider two regimes: for national-power and for regional-irrigation. Thus all accounts in models we shall carry out for time units equal to one month with use of monthly average of parameters.

Basic settlement formula for production of energy on hydroelectric station after transformations shall present as:

\[
\eta = 9.81 \eta \left( \frac{Q}{3600} \right) \left( \frac{H}{3600} \right) \quad (9)
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As a changing parameters in both models the consumption of water through turbines of hydroelectric station are accepted.
The criterion of optimization of operational regime of Kayrakkum hydroelectric station from a position of national interests of water-power engineering is defined practically unequivocally i.e. maximization of production of energy in winter: from October till April (May) without any other conditions for other period of year.
A criterion of irrigational regional operational mode of Kayrakkum reservoir is defined by need of water in vegetation period required by countries Uzbekistan and Kazakhstan.
Both models were developed with the use of personal computers in framework of programs Microsoft Office1998 or Excel and menu Service.
The algorithms of a simplex method and method “branch-and-bound” for the decision of linear and nonlinear tasks with restrictions are developed by Yohn Watson and Dan Fulstra, Frontline Systems, Ync.
For conducting of concrete calculation on mathematic models the fact sheet, which were in use for the last years (1998-2001) have been used.
The results of calculation are shown in Fig. 2.
Comparison of results of these two models allow to define those direct losses of produced energy, which bears Tajikistan rendering service on irrigational regulation of flow for Uzbekistan and Kazakhstan. They are equal to:

\[ 719,183-472,334=246,849 \text{ mln.kwthour} \]

As characteristics of this mode it is possible to note that for maintenance of the maximal production of energy in autumn-winter period there is no necessity of be complete function of reservoir up to its minimal volume 881,1mln.m^3.The minimal volume of reservoir during its energy mode is1600, 7mln.m^3.
Received results allow that by using of market approach to optimize the use of water energy resources of river on international level.
Figure 2. Energetic and irrigation scheme of operation and accumulation of Kayrakkum reservoir (a), Monthly average drawn downs from Kayrakkum reservoir in energetic and irrigation regime (b)

4. CONCLUSION

To certain extend it can provide considering by us the maximization of regional benefit but with taking into consideration the social aspects. It is that: In conditions of priority for life-support of Central Asian Countries and irrigational farming in practice will be implemented irrigational regulation of flow while the criterion will be the maximum provision of water for irrigated agriculture in vegetation period. Countries of lower flow should compensate the loss of energy, which bears the countries of upper flow, getting by result of such scheme the additional water for irrigation. Such a scheme was implemented in Central Asia for the most intense river pool – Syrdarya of Aral Sea. In 1998 among Kirgizstan, Tajikistan Turkmenistan and Uzbekistan the “Agreement of using of water-energy resources of the river pool Syrdarya” was signed. This agreement successfully worked during 5 years and in 2003 was prolonged by Central Asian Republics for five years.