Comparison of Production on a Cascade-Connected Hydro Power Plant, with Daily and Monthly Reference

Mile Spirovski[1] , Arsen Arsenov[2] and Acevski Nikolce[3]

Abstract – **This paper work deals with the area of exploitation of electro energetic systems bound with accumulations that are hydraulically connected. That type of connections produce complex exploitation, consequently the work of any power plant from the hydraulic array is influential on the work of the other accumulation and the power plant of that accumulation. There professional packages like HEC DSSVue and HEC5 are used. Using the huge data base in which beside the given there is a hydrological array of data for accumulation hydrographs, there are elaborated associated accumulations work simulation in tandem connection and parallel connections.**

Keywords – **Cascade connected hydro power plant, .**

I. Introduction

This paper deals with the area of exploitation of electro energetic systems bound with accumulations that are hydraulically connected. That type of connections produce complex exploitation, consequently the work of any power plant from the hydraulic array is influential on the work of the other accumulation and the power plant of that accumulation. Additional hardship is created by the numerous restrictions that have to gratify the power plants like one complete unit, for example: minimal and maximal licensed expiration through captivation constructions care for the capacity of the addictive pressure tube and narrow drainage passage, allowed velocity quickness of increase drain through tubes, changes of the accumulations rates satisfying the given hydrographs which define direct water takeoff from the analyzed accumulation for drinking water, industry, irrigation systems. A special problem during the exploitation of accumulation systems is the management while crises occur, like in the flood periods.

In this paper, withstanding the basic principles for maintained continuity and mouth of movement, some methods for hydrograph transfer analysis through accumulations and canals are elaborated. Professional packages like HEC DSSVue, HEC5 for the determination of technical and energy parameters of hydro power plants are used, in the content of accumulations and the accumulations themselves. By using world experiences connected with the exploitation of accumulations allocated criteria for accumulation use are elaborated. Using the huge data base in which beside the given there are hydrological array of data for accumulation hydrographs, associated accumulations work simulation in tandem connection and parallel connections are elaborated. With respect for the special conditions and restrictions for given system reservoirs on the river Treska simulations for daily working regimes are performed. The results are presented in the paper in tables and graphical form.

The results of the analysis show that the system of hydroelectric power plants HPP Kozjak, HPP “St. Petka” and HPP Matka 1 is a well projected system besides the small amount of over spills that Matka 1 can obtain even in an average year. Results of the simulations show us the introduction of equivalent accumulation and exploitation of accumulation system criteria on the basis of criteria for maintenance equivalent level is usable in our conditions, but has not been used in our past experiences which can be concluded from the technical data for the present and new in the future energetic constructions. Some difficulties connected with the secure biological minimum of HPP Matka 1 can be perambulated by giving a special task for that purpose to HPP “St. Petka”, HPP Kozjak or to both of them, which is expressed on their potential production of electrical energy.

II. Analyse of Cascade Work of the Hydro Power plant on River Treska

In this paper accumulations and their energy and hydraulic restrictions, as well as other characteristic will be processed on the cascade connected system on the Tresca River, given on figure 1. The HPP St. Petka and HPP Matka 1 have a smaller size of accumulations in respects to HPP Kozjak, and we must economic calculate with them.

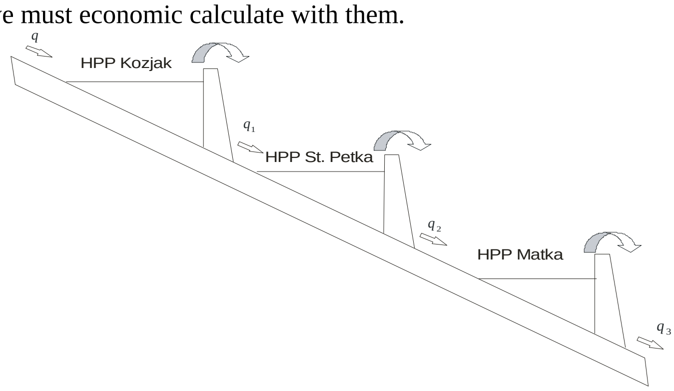

Fig. 1 System on the Treska River.

HPP Kozjak is the first of the series of cascade connected hydro power plants on the Treska River. In Kozjak are installed two aggregates, both of them with $50m^3/s$

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TABLE I
POSSIBLY SOLUTION FOR FRANCIS TURBINE ON HPP KOZJAK

Solution Number	Runner Diameter Millimeters	Runner Diameter Inches	Unit Speed rpm	Specific Speed NS	Centerline Setting meters
1	2673	105.2	214.3	157	2.4
2	2747	108.1	200.0	146	3.3
3	2820	111.0	187.5	137	3.9
4	2885	113.6	176.5	129	4.4
5	2945	115.9	166.7	122	4.8
6	3004	118.3	157.9	115	5.2
7	3063	120.6	150.0	110	5.6
8	3122	122.9	142.9	104	6.0
9	3169	124.8	136.4	100	6.1
10	3216	126.6	130.4	95	6.2

Preliminary Output: 38892 KW

Enter Size Selection: 1 Continue Cancel Help

TABLE II.
TYPICAL PERFORMANCE FOR FRANCIS TURBINE ON HPP KOZJAK

Solution File Name: c:\kozjak.dat — Turbine Performance Data - Typical

Close Next Page Print Report Display Input Definitions

Performance at rated net head of: 88.1 meters

m3/s	% Eff	KW	% Rated	
51.22	92.7	41054	102.4	**
50.00	93.0	40209	100.0	
45.45	93.5	36737	90.9	*
37.50	92.3	29913	75.0	
25.00	83.1	17962	50.0	
12.50	58.8	6351	25.0	
27.14	85.6	20083	54.3	+

** Overcapacity * Peak Eff. Condition + Draft Tube Surging peaks

Efficiency Modifiers: Multiplier: 1.0000 Flow ^{2} Function: 0.0000

Maximum Output Performance

At maximum net head of 89.0 m		At minimum net head of 70.0 m	
41297	KW	28786	KW
92.8	% Eff	90.2	% Eff
50.97	m^3/s	46.48	m^3/s
0.087	σ allow	0.111	σ allow

Runner Diameter: 2673 mm
Speed: 214.3 rpm

σ allowable at 100% KW and Rated Net Head: 0.083
σ plant at 100% KW and Rated Net Head: 0.088
Maximum Runaway Speed: 369 rpm (at the Maximum Net Head above)
Flow at Runaway Speed: 28.0 m^3/s (at Rated Net Head and 100% Gate)
Flow at Speed-No-Load: 4.78 m^3/s (at Rated Net Head)
Site Atmospheric Pressure minus Vapor Pressure (Hatm - Hvp): 9.79 meters

Unit Centerline to T.W.: 2.0 meters

Specific Speed under Rated Net Head:
152.2 at Peak Efficiency
159.2 at 100% Output

discharge. The professional program HEC5 gives 10 possible solutions for hydro turbine, with characteristics that are given on Table I and Table II where the maximum output performance, net head, discharge, coefficient of cavitation etc are shown.

Saint Venan equations, also named basic equations, are used to describe the spreading of the given water wave in an open canal. Depending of how much is the number of elements in the structure of a model which describes the movement of the wave, water waves can be classified as: dynamic waves, gravitation waves, diffusion and kinematic waves. For example, the dynamic wave foresights all the members in structure of Saint Venan equation for keeping the quantity of movement. Gravitation wave disregards the effect of obeisance on trough, and the effect of rubbing which develops between the water and the walls of the river.

If we disregard the article $g(S_0 - S_f)$, we take other articles in the equation for maintenance quantity of movement. A kinematic wave takes only the effects of existing scrap which develops between the water and the walls of the river trough. For Saint-venan equations we can write:

- Equation for keeping the continuity:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \tag{1}$$

- Equation for keeping the quantity of movement, or equation for keeping the impulse.

$$\frac{\partial Q}{\partial t} + \frac{\partial (Q^2/A)}{\partial x} + gA\left(\frac{\partial y}{\partial x} - S_0\right) + gAS_f = 0 \tag{2}$$

Where the x is distance thought the river in m, t is time in s, A is the surface of a transverse cut in m^2 , y is level to surface of the water to the canal in m, So is bottom scrap to the canal (negative): q is inflow of water (continual inflow of water thought the unit length of the canal-from the lateral side) in $(m^3/s)/m$; S_f is the incline of scrub and it can be determined with help of the equation of Manning:

$$S_f = \frac{n^2 Q^2}{A^2 R^{4/3}} \tag{3}$$

and g is earth acceleration, in ms^{-2} .
R is hydraulic radius, Q is expiration in m^3/s; n is coefficient of roughness or Manning coefficient.
Equations (1) and (2) can be written in this form:

- Equation for keeping maintenance:

$$B\frac{\partial h}{\partial t} + \frac{\partial Q}{\partial x} = q \tag{4}$$

- Equation of keeping the quantity of movement:

$$\frac{\partial v}{\partial t} + \alpha \cdot v\frac{\partial v}{\partial x} + g\frac{\partial h}{\partial x} - g\left(S_0 - S_f\right) = 0 \tag{5}$$

B is amplitude of the glass area to the water in the canal (m), α is a coefficient of allocation of the speed through a given cross section, h is depth of water in the canal (m),

III. BASIC EQUATIONS OF CONTINUITY

Counting methods related to transfer of hydrographs through canals and accumulations are based on the principles of keeping the mass (continuity equation) and keeping the dynamic equality of the impulse.

Continuity equation is shown keeping the mass which means that the change of accumulation is equal to the inflow of water, minus expiration:

$$I - O = \frac{dS}{dt} \tag{6}$$

t is time in seconds, and S is accumulation volume (m^3), that is the volume between two sections in the canal. I is inflow in m^3 (is inflow entry and any other which is entering into the canal between two sections), O is expiration in m^3/s, (here is the out stream and any other lost of water, for example infiltration over the bottom of the canal, taking water for other needs and other sort of taking away).

The equation for keeping the quantity of movement is a dynamic equation and it is the same as the Second Newton law: according to the change of quantity of movement it's the sum of all strengths which effect the examined volume,

$$\frac{d(mv)}{dt} = \sum F \qquad (7)$$

Namely, m is the mass in kg, v is the speed in m/s, moving to the water volume between two sections into the canal. The sum of the strength F includes the pressure, rubbing and gravitation conditions.

The transfer of mass includes decision which takes foresight of the continuity equation and equation of a moment.

As a result of the analyses of a daily work to hydro power plants of Treska River inclusive results are received in table and diagram forms. Table results are represented in a 1000 pages and because of their inclusive are not shown in paper work. Only the interesting results are represented in graphic form. As a result of the analyses the following dependencies of: level of three accumulations in a function of time, time dependencies of net falls of the center, capabilities, expected productions, expirations, factors of power plant, natural, regulated and cumulated hydrographs in places named as control points are received. At the same time results of the accumulation level in any temporal period are received. Special specification of this output results indicate a so called case analysis that allows for any precise expiration in a different time interval to give a reason for that expiration. Accumulations of three power stations, especially HPP Kozjak should be exploitive in any time of the year, at the beginning and at the end of the year have same level. Certainly, accumulation of HEC Kozjak is over year so, if they want to use it the same as it is it's necessary to specify the wanted level, and at the beginning and end of the year it can be different. Used program support gives opportunities to define a benchmark level, to attach a bit in determined seasons or at the end of the month.

Beside technical and power characteristics for accumulations and hydro power plants, to realize the power analyses, we can use the hydrological diagram to water inflow in any accumulation. In this case, foresight is taken only for the hydrograph of Kozjak accumulation and other inflows are ignored and there is no problem to foresight it. Ignoring is made for the easy following of the received results. In fig.2. the hydrograph of HPP Kozjak is shown in two ways: continual curve presents the curve of mid-day inflow in this accumulation for the year 2004, which was transgression year and because of that, the number of elaborated time intervals is not 8760, but 8784 time intervals. On the basis of the average month inflow, that hydrograph is shown in a same picture with broken line. The hydrograph for a month average inflow, at the analyses is calculated that in any day, in any time interval, thought one month the inflow is the same to the average month. This idea to select hydrograph represented in two ways is to examine influence of month hydrographs, when are used for daily simulations of work to the hydro power plants. This thought is based of the fact that in practice, we have in disposal with average month hydrographs on a given location, than with average daily hydrographs.

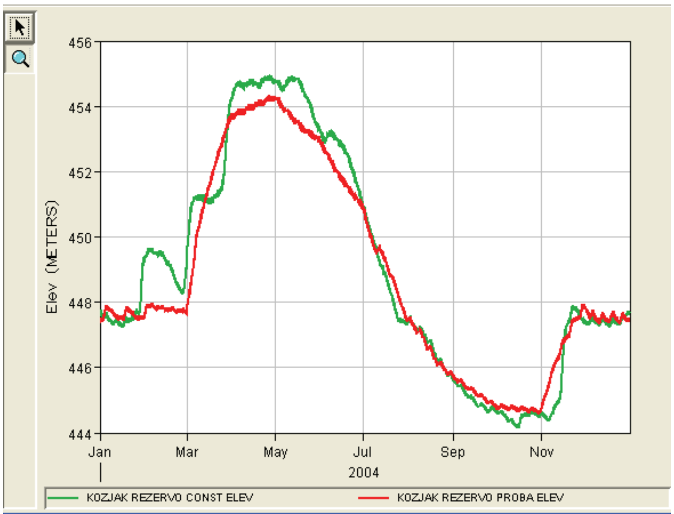

Fig 2. Hydrograph with medial inflow with month and daily parameters.

IV. Result Related to HPP Kozjak Accumulation

On fig.3 are represented the changes of levels to HPP Kozjak accumulation, in case at hydrograph of the standard daily inflows and standard month inflows on a base to daily. We can conclude in that case of hydrograph usage, with standard daily inflows, oscillation of levels in fig3 (in wet and dry seasons all over the year.

On picture 4 and 5 are illustrated the change of levels, accumulation levels, outflow, and expected production of power energy for HPP Kozjak, in a case of month and daily inflows. We can see that all variables are in the permitted circle. It can be seen that oscillation of levels are in permitted reservoir levels, and there are periods through the year when HPP Kozjak accumulation is under level, and it is same to the Buffer volume, which is a result of the HPP Kozjak task (to control biological minimum at HPP Matka1). When HPP Kozjak works with a lesser flow, it doesn't produce power energy, because its flows are not enough for moving the hydro turbines.

From this index levels it can be seen that HPP Kozjak accumulation will never achieve 3 level (conservation level). Analyses shows that in a case the duties for biological minimum at HPP Matka 1, assurance HPP St. Petka, then HPP Kozjak accumulation for a long time it is going to work whit level that is responsive to level 3.

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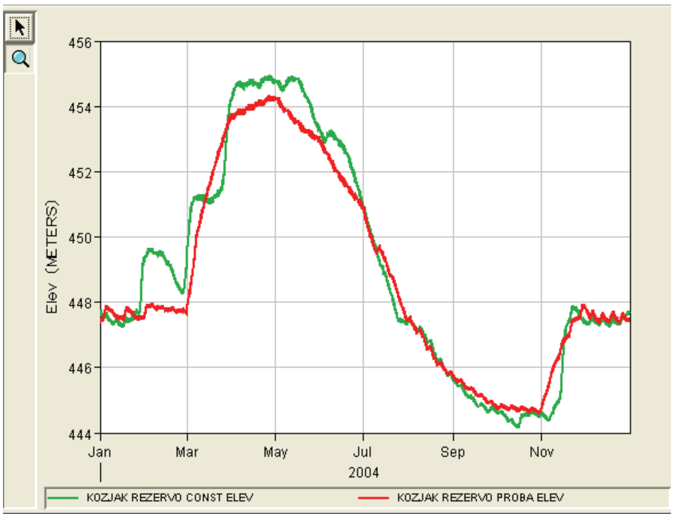

Fig 3. Variety of level on accumulation on HPP Kozjak

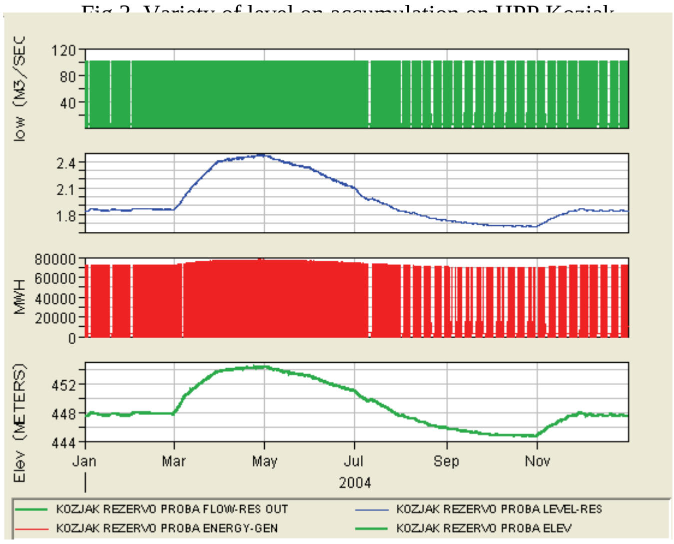

Fig 4. Optimal outflow, levels, energy generated on HPP Kozjak with monthly parameters.

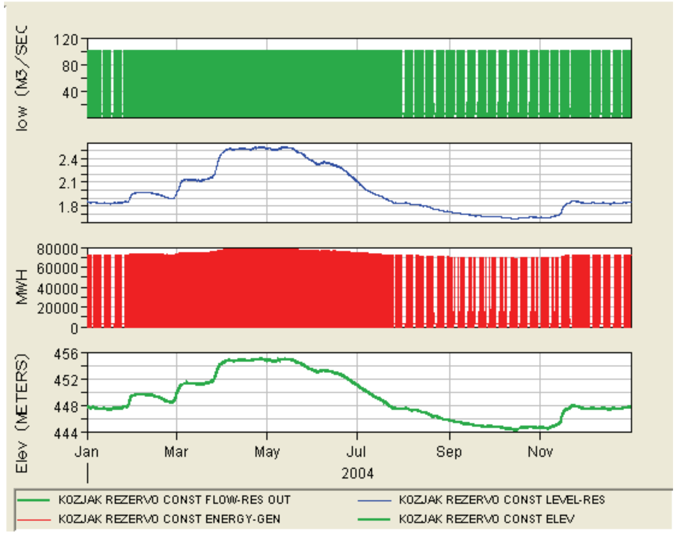

Fig 5. Optimal outflow, levels, energy generated on HPP Kozjak with daily parameters.

V. CONCLUSION

There is an elaborated and used program software for complicated power analyses and its usage in all conditions is adapted.

It can be concluded that the differences in the results are unimportant, dispensable of that if simulations are made with hydrograph on the principle of standard daily inflows or standard monthly inflows. That means, technical documentation, practical in all levels can be produced, with exactness, and with hydro bases (like the bases in our country).

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