IMPROVEMENT OF PICO HYDROPOWER PLANT ON THE RADOVANSKA RIVER

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Abstract: The work carried out numerical simulations of flow in a small bulb turbine using the software package CFX. The turbine was installed in one of the pools of a trout farm Jablanica in the Radovanska river. Built small pipe turbine was unregulated. In the periods of low discharge the turbine was inactive. An improvement of built-in turbine has been done installing regulated inlet guide vanes. The first, using CFX software, power efficiency curve of unregulated bulb turbine had been obtained. Then, power efficiency curves of the turbine for several different positions of inlet guide vanes were calculated. Comparisons of the efficiency curves of analyzed turbines were performed. The advantage of the solution with regulated inlet guide vanes was shown. The described solution was built in the hydropower plant.

Keywords: bulb turbine, flow simulation, turbine regulation

1. INTRODUCTION

The Radovanska river is located in Eastern Serbia in the region of municipal city Boljevac. On the left bank of the river, near to it's underground exit trout farm Jablanica has been built. Following the fall of the field parallel to the river, there are six concrete pools cascading set for trout farming. Apart from these pools, there are two large pools built in clay excavation.

Micro-climatic conditions of trout farm are suitable for life and growth of trout varieties of fish because there is no freezing of water during winter. The farm is located in a valley surrounded by mountains that protect it from the winds.

Average mean flow of the river, according to data from the official registry, is 350 l/sec at the site of water intake. In the dry season the water flow drops to about 100 l/sec. Drought is customary during autumn.

Water intake, which is located on the concrete bulkhead river, is Tyrol type. Since the affected water contains drawn and suspended sediment behind the intake, there are two pools for deposition of sediment. Then the water is released into the fields for growing fish.

For the current production levels pond uses an average of 250 l/sec of water. Minimum amount of water is dependent on the time of year, the amount of fish that are grown and feeding intensity.

When there are unfavorable hydrological conditions, the amount of water used is less than 90 l/sec. In such situations it is necessary to perform the aeration of the water to increase the oxygen content.

Pond is not connected to the public electrical grid. Required electrical energy was produced using fuel oil generator. According to the cadastre of small hydropower plants, in the immediate vicinity of the pond, it has been planned to build a small hydro power plant. It is not certain when that will be.

From the above described the idea arose that the water used in the process of raising fish at the outlet of the pond can be used to produce electricity. Namely, after the fish ladder, which are arranged in cascade in four levels, the water is collected in the sump and discharged into the river.

The relative elevation of the water table in the collection basin is 94.50 meters and the elevation of the water in the drain channel is 92.20 meters. As seen on Figure 1 there is a drop of 2.30 meters which could be used for power generation turbines.

Hydraulic losses would be small due to the small length of penstock and profiled inlet of the tube. Penstock diameter is D=430 mm and its length 8.10 meters.

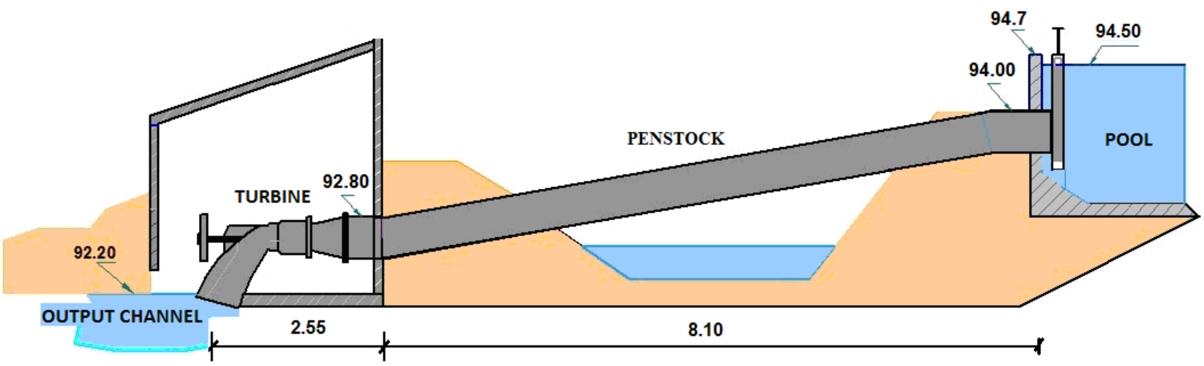

Figure 1

In 2011. pico hydropower station was built. Unregulated bulb turbine was installed. The geometry of built-in turbine had been obtained by scaling the small tubular turbine of known geometry and characteristics [1,2]. Impeller diameter turbine has been 300 mm, and penstock diameter 430 mm. The

output diameter of the diffuser has been 500 mm, the length of the diffuser 950 mm, so that the angle of the diffuser has been 6^o. The turbine had secured a stable supply of electricity in gross head from H=1,80 to H=2,30 meters. It's rotation speed was n=320 rpm and optimal efficiency discharge of Q=210 l/sec. Asynchronous generator has worked at 760 rpm.

Implemented solution photos are given in Figure 2.

Figure 2

In dry periods, when flows are lower, unregulated bulb turbine couldn't provide the minimum power necessary for the stable operation of the system. Electronic speed controller of the turbine, which had been working on the principle of sharing power between ballast heaters and consumers [3], during dry periods system operation was often interrupted due to lack of power. Therefore, fixed guide vanes of the turbine were replaced with adjustable guide vanes. Turbine impeller has remained unchanged. Implemented solution to the problem is described in this paper.

Previous unregulated and new regulated turbine solutions were simulated using CFD software Ansys CFX. The results of calculations are presented in the work. Detailed description of the calculation results was given for the previous turbine solution in [4], and for new turbine solution in [5].

2. PREVIOUS TURBINE SOLUTION – UNREGULATED TURBINE

Based on the dimensions given in the introduction to the paper geometric model of previous turbine solution was established. It had impeller with 4 fixed blades and 7 fixed guide vanes. Shape of guide vane was curved, as part of a cylindrical surface. The blades of impeller and guide vanes were made from sheet metal of constant thickness. The thickness of the blades of the impeller was 5 mm, the thickness of the guide vane was 3 mm. Incoming and outgoing edges of the impeller blades and guide vanes are round-arched.

Discretisation mesh was formed using the program CFX-Mesh and Ansys TurboGrid. CFX-mesh was used for the preparation of unstructured mesh of input and diffuser. The mesh was adjusted to the application of wall functions. The program Ansys CFX, when using the SST turbulence model, predicted the automatic transition of the laminar sub-layers to the wall functions, depending on the dimensionless coordinates y^+. For the formed mesh, dimensionless thickness of the first layer of the mesh was $y^+ < 2$, according to recommendations for the calculation of the laminar sub-layers.

Geometry of previous unregulated turbine is shown in Figure 3

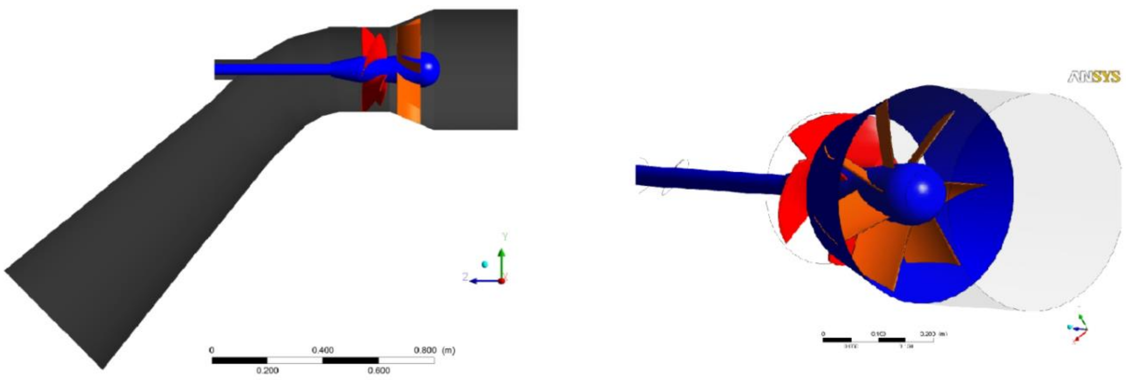

Figure 3

Using software Ansys CFX, the characteristics of unregulated turbine were obtained. The calculation results are given in Figure 4.

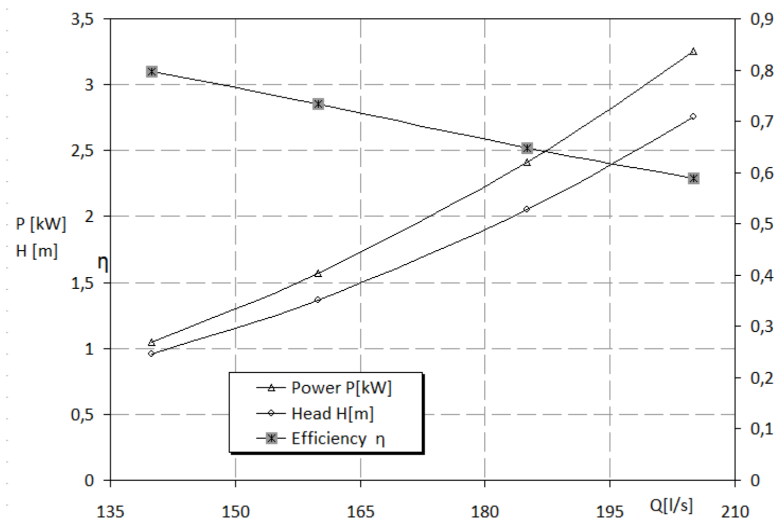

Figure 4

As mentioned in the introduction, this unregulated turbine had been operated at gross heads between H=1.80 and H=2.30 meters and at discharges greater than Q=180 l/sec.

3. NEW TURBINE SOLUTION – ADJUSTABLE GUIDE VANES

In order to provide electricity during the whole year, reconstruction of the existing unregulated turbine started. It is obvious that the problem can be solved by regulation of the turbine. The old, unregulated turbine impeller was retained, and regulation was achieved using adjustable guide vanes. This solution minimized the costs and shortened the time of implementation.

The preliminary technical solution is presented in Figure 5.

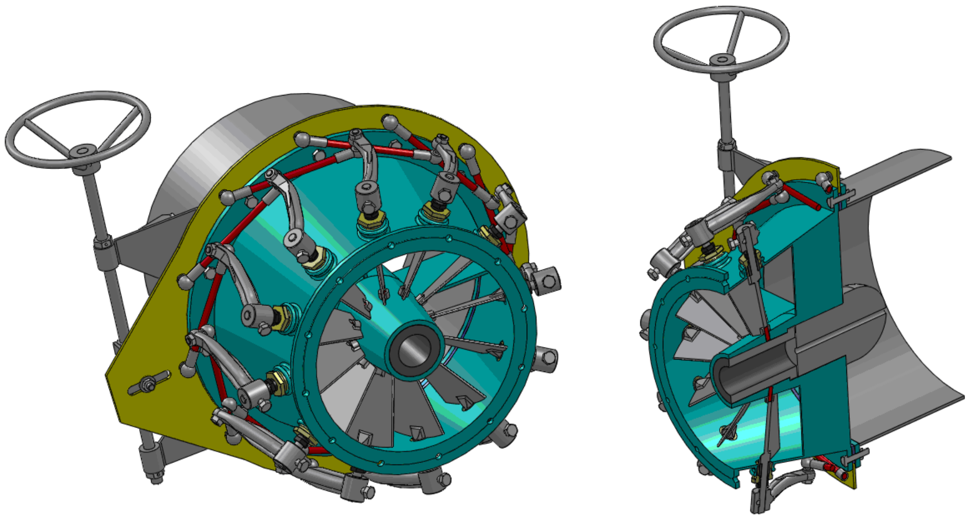

Figure 5

Reconstructed turbine had 12 guide vanes. Moving guide vanes were flat plates with a thickness of 3 mm. The calculation was performed for 4 angles $\alpha = 15^0$; 30^0; 45^0; 60^0 of the guide vanes. Calculation procedure was identical to the already described for the case of the unregulated turbine.

Grids of the impeller blade and the guide vanes for $\alpha = 45^0$ are given in Figure 6.

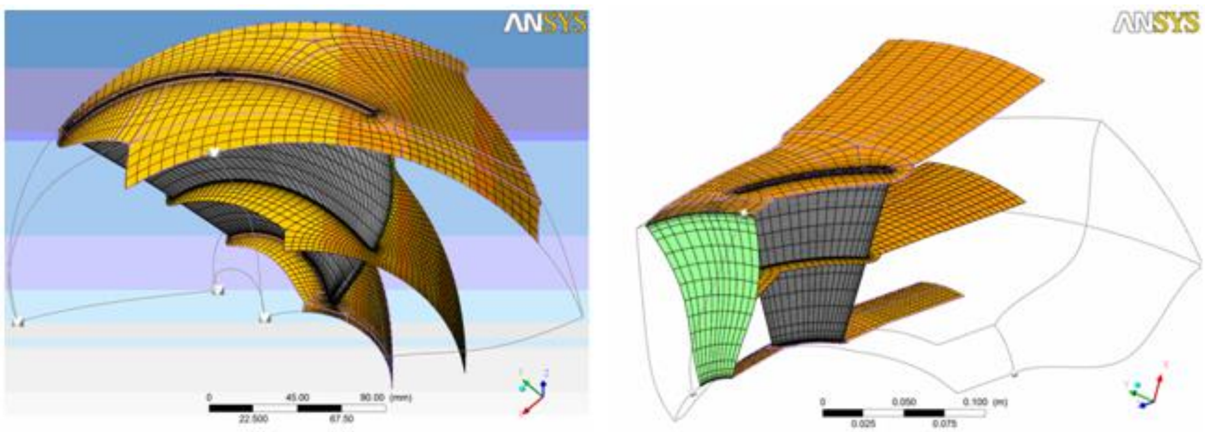

Figure 6

Grid of the diffuser is shown in Figure 7.

Figure 7

Description of the calculation procedure was given in detail in [5]. Figure 8 shows the results of calculations for gross head H=2.30 meters for the whole range of changes in the angles of guide vanes.

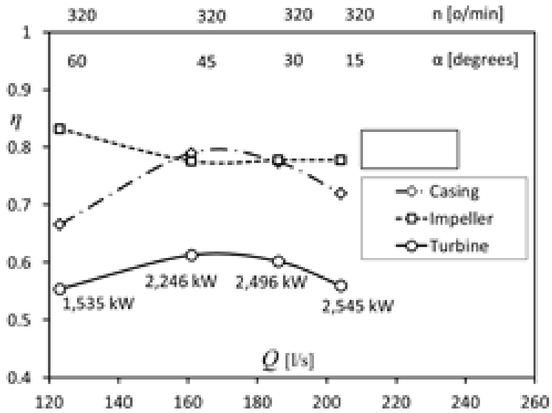

Figure 8

On the basis of calculations performed, during the autumn of 2013, turbine with adjustable guide vanes was produced. The photo of produced adjustable guide vanes is shown on Figure 9.

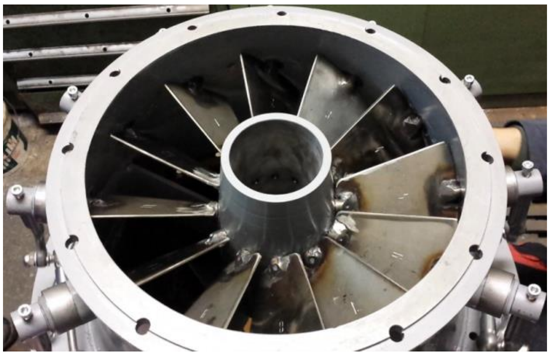

Figure 9

It turned out that the turbine, in the range of gross head of H=1.80 to H=2.30 m and discharges greater to Q=90 l/sec, has worked stable. The proposed and implemented solution has provided permanent work of the hydropower station throughout the whole year.

The price of the implemented solution, with adjustable guide vanes as flat plates, is somewhat lower turbine efficiency coefficient in the discharges greater to Q=180 l/sec. For example, at discharge of Q=192 l/sec, efficiency coefficient of the unregulated turbine is $\eta = 0,627$ and of the regulated turbine $\eta = 0,588$. It is seen, that the relative difference in turbine efficiency coefficient, of unregulated and single regulated turbine is 6.2% relative to unregulated turbine.

4. CONCLUSIONS

For unregulated turbine there were carried out simulations in the area of gross head of H=1.80 to H=2.30 meters and the domain discharges of Q=120 l/sec up to Q=210 l/sec. It turned out that the unregulated turbine was stable for discharges Q > 180 l/sec. Unstable operation of pico hydropower station occured during the autumn months, when the plant was not working.

The problem is solved by introducing a regulation of the turbine guide vanes. Because of the need for quick solutions, 7 fixed cylindrical guide vanes was replaced with 12 adjustable guide vanes. Adjustable guide vanes are flat plates. Regulated turbine operates in all flow conditions during the whole year, ie. with dischages Q > 90 l/sec.

The price of the implemented solution is reducing the turbine efficiency coefficient approximately 7% in the domain of Q > 180 l/sec. The produced electricity is sufficient for the needs of island operation of electric devices in the trout farm Jablanica.

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