DEVELOPMENT A MICRO HYDRO POWER SCHEME AT THE WEIR ON BLACK TIMOK*

by

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The micro hydro power scheme (MHPS), as a practical realization of research project supported from Ministry of Science of the Republic of Serbia, is presented in the paper. MHPS was constructed on the Black Timok (East Serbia) at the deserted weir. MHPS can be used as a model for other similar sites with extremely low head. On this way, the contribution to approaching to Directive EU for renewable energy sources was done. The results of project are summed in the paper. The method of turbine type selection by use of nomogram is presented. The results of dimensions scaling of existing smaller turbine are given. On the base of these results, the turbine of 5 times higher dimensions was designed and made. The results of estimation and measuring the parameters of this turbine are compared. Designed and constructed powerhouse of MHPS, which is jointed to existing weir, is described. The results of energy efficiency and ecological effects analysis of MHPS are given in the paper.

Key words: *micro hydro power, turbine, powerhouse, distributed grid*

Introduction

The concrete weir on Black Timok (East Serbia) was constructed fifty years ago. At the beginning, the weir was used for small thermo power and, later, for irrigation system. At the past 30 years the weir has not been used. The author of this paper decided to construct the micro hydro power scheme (MHPS) as a model for similar sites. The project was supported from three local companies and from Ministry of Science of the Republic of Serbia. The project included: hydrology study, designing the MHPS, designing and construction the turbine, construction the MHPS, testing and starting the MHPS, and analyze of MHPS operation.

Selection of a turbine

For selection of a turbine the nomogram in fig. 1a was used [1, 2].

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The nomogram shown was used as follows:

(1) head available (H 2 m) was marked, turbine output power from the following equation was calculated, and rule line was crossed,

(2) turbine output power is: $P_t = \eta 10QH$ [kW], $P_t = 40$ kW, for Q 2.5 m^3/s – water flow; η 0.8 – efficiency of reaction turbine types, and

(3) desired turbine running speed was chosen (150 rpm is slowest speed advised if an induction generator is to be run at 750 rpm, for belt drive or mechanical multiplicator between turbine and generator) and a line from this point was drown at right angles to the head-power line.

Approximate runner diameter was estimated from nomogram (fig. 1b). The nomogram is used exactly like fig. 1a. First, we decided the most suitable turbine type, than consult this nomogram to approximate the runner diameter. The axial propeller S turbine type of 1000 mm diameter was chosen. After that, the author and engineers of project supporting company were constructed the turbine.

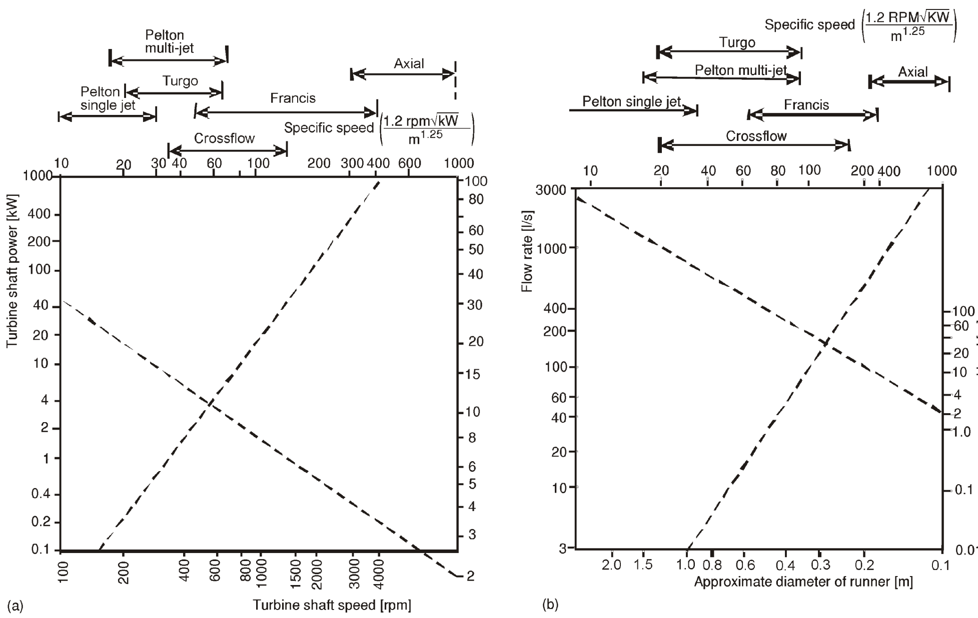

Figure 1. Selection of a turbine for a hydro site

The geometry of turbine runner identification

The author had the small propeller turbine of 200 mm diameter (fig. 2), which was used as a model for designing the real turbine of 990 mm.

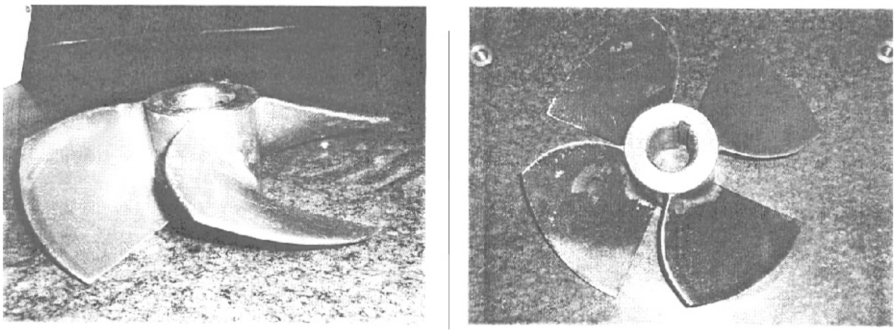

Figure 2. Model of turbine runner

The measuring of runner geometry was realized by three-axis numeric measuring coordinate machine DEA EPSILON 2304. Computer support to measuring machine is realized by use of computer MICRO PDP 11. Measuring precision is 0.005 mm. The measuring results where worked out by use of CAD/CAM program UNIGRAPHIC II [3]. The numeric three-dimension model of running blades and runner was given from turbine model. The mass-characteristic of runner model and the prediction of mass-characteristic of scaled real runner were given. On the base of measuring results, the geometry of runner turbine model was generated by use of software SOLID EDGE 1.6 [3].

After the measuring and definition of three-dimension runner model, the scaling of their dimensions were carried out. The dimensions were increased 4.95 times. The graphic view of blade was given in fig. 3. The geometry of increased blade surface is necessary for coining the blades. The blades were made from still plate of 12 mm thickness.

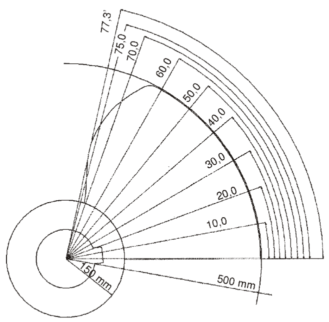

Figure 3. Graphic view of modeled surface of 4.95 times increased blade

The obtained results were used for:

(1) making the tools for blade coining,
(2) modeling the geometry of real turbine and calculating the water flow through turbine by method of finite volumes and by software FLOWLAB, and
(3) modeling and calculating of dynamics of runner and generator connection.

Estimation of turbine characteristics

For estimation of turbine characteristics the geometric and mass-data of real turbine obtained for turbine model [4, 5], and hydraulic characteristics given for one working regime by manufacturer, were used.

For prediction of turbine use area the software was developed and diagram in (Q, H) system was used. The usefulness of software was verified by the calculation of area of use for propeller turbines of other manufacturers [6]. For this calculation the following relations were used:
- relation for total power at coupling of turbine shaft and relation for internal power at turbine shaft exit [5],
- correlation between turbine model and real turbine, which is given from dimension analysis of theory of similarity [7], and
- relation for turbine hydraulic efficiency [7].

On the base of given calculation and corresponding software the area of use of real propeller turbine was established from fig. 4.

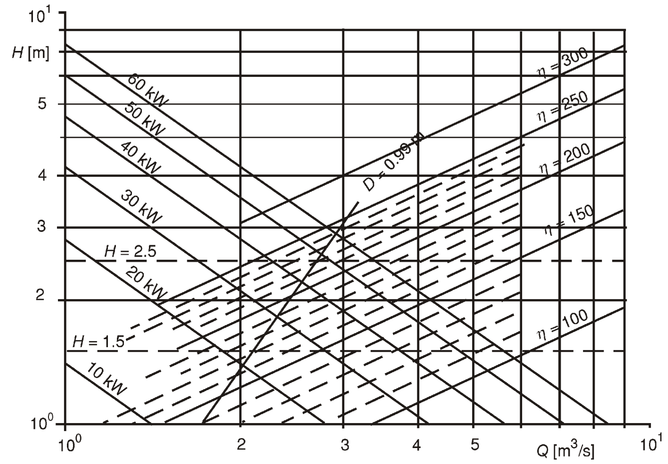

Figure 4. Prediction of area of use for real propeller turbine

Design and construction of micro hydro power scheme

From hydrology study, the medium year flow in the river bed of Black Timok is 11.5 m^3/s. The design of MHPS included three propeller turbine of 990 mm runner diameter. In first phase of design the montage of one turbine was predicted (fig. 5). The powerhouse of PHPS first phase, with following objects was constructed (fig. 6).

The powerhouse was jointed to existing weir and it is near the river bed. The head of existing weir is low, H = 1.5, and 2.5 m after adding of logs. The hydrostatic pressure is low and it was possible to put the powerhouse in the body of existing weir. At the entry of powerhouse, in the weir, the entrance still pipe of 1.4 m diameter was installed. Exiting turbine siphon gradually transforms diffuser which is formed from powerhouse walls. At the pipe entry and at the diffuser exit the stop logs were installed. In front of entrance log it was installed the rack. At the powerhouse exit the tailrace and wing wall of river was constructed. The water is directed from river to the turbine pipe through the forebay with silt basin. The concrete threshold was installed between forebay and river flow.

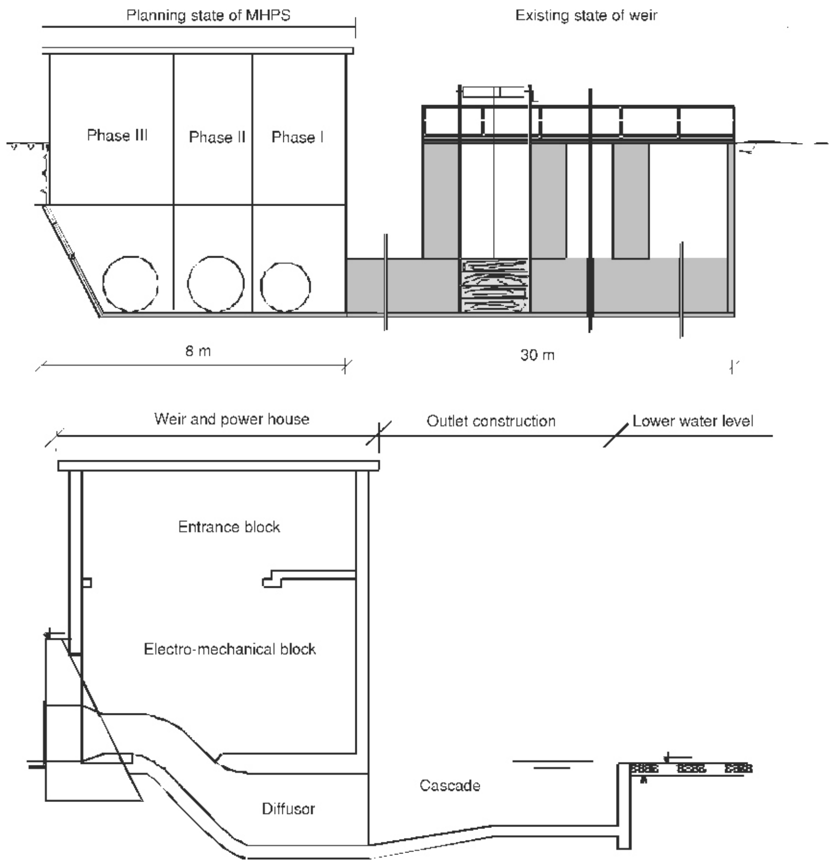

Figure 5. The lay-out of vertical section of designed powerhouse

In the powerhouse was mounted the equipment: propeller S turbine of 990 mm runner diameter, induction generator of 40 kW and 750 rpm synchronous speed, belt drive of 5:1 speed ratio. The switch-board and measuring board were installed near the powerhouse entrance, above the generator. The switchgears, measuring, and protective elements were installed on switchboards in boxes. The capacitor for compensation of reactive power was mounted under switch--boards.

Figure 6. The photo of constructed MHPS, existing weir, and added logs

From the busses in measuring box, start the low voltage cable, type NYY-A-4 95 mm^2, which was laid on internal powerhouse wall. Outside of powerhouse the cable was laid in existing pipe of 300 mm diameter, which was installed across the river and, farther, under the road and in the trench to existing transformer station of 10/0.4 kV 630 kVA. The length of cable is 150 m.

MHPS was connected to regional distribution grid which includes one more MHPS of 320 kVA which is in exploitation from 1909, and which is one of first MHPS in Serbia.

The power of constructed MHPS, in this first phase of construction, is 40 kW. In second phase, predicted installed power is 100 kW.

The results of measuring of parameters, during MHPS working

After the working start of MHPS, the mechanical, electrical, and protective equipment were tested. For head of 2.5 m the electrical power of induction generator is 38 kW. The manufacturer of turbine model (of 200 mm runner diameter) gave, for certain working regime [4], summary efficiency (turbine – generator) of 0.6. In the case of real turbine (of 998 mm, runner diameter) the "effect of dimension" [7] increases the efficiency, and belt drive between turbine and generator decreases the efficiency. From fig. 4 for head of 2.5 m the maximal flow is 2.5 m^3/s. Using the formula (1) for electrical power of 38 kW (which was measured) summary efficiency of 0.6 for system real turbine-generator was given. On this way, the efficiency is equal to efficiency of system turbine model – generator.

Energy efficiency and ecological effects of constructed MHPS

Construction of MHPS on Black Timok enables to make good use of potential energy of forebay, which was constructed 50 years ago for small thermo power and irrigation and which was given up, afterwards. The energy of 280,000 kWh per year is obtained on this way, in first phase of MHPS. After the realization of second phase, it is expected to obtain the electrical energy of 500,000 kWh per year. On this way, the contribution to use of energy from renewable sources in Serbia is given.

On the base of expected electrical energy production, in first and second phase of MHPS, the coal economy (because of thermal power substitution) was determined [4]. The calculation was carried out by presumptions: 33% efficiency for combustion of coal of 9,000 kJ/kg lower thermal ability.

After the calculation, expected year economy of coal is 340 t, in first phase, and 607 t in second phase.

Expected year decrease of CO_2 emission is 349 t in first phase of MHPS and 623 t in second phase. Expected year decrease of ashes quantity is 68 t in first phase and 121 t in second phase.

It is known, in distribution system which includes the distributed generation, the energy loss is lower and potential state is better, than in distribution system without distributed generation. Using a data for parameters of transmission lines and transformers, and for power in consumer nodes, it was performed the calculation of node potentials and power losses in elements of distributive grid with MHPS [8]. The calculation was performed in cases of distributive grid: (a) without MHPS, (b) with first phase of MHPS, and (c) with second phase of MHPS (tab. 1).

Table 1. Power losses in distributive grid without and with MHPS

	P_G [kW] at cos φ = 0.95	ΣP_{loss} [kW] (summary power losses in feeders)	P_{loss} [kW] (power loss in transformer)
Without MHPS	0	25.64	1.53
First phase of MHPS	40	25.12	1.16
Second phase of MHPS	100	24.52	0.763

Conclusions

The model of MHPS which was realised at deserted weir with extremely low head, is applicable for similar sites, enables wide use and approaching to Directive of the European Parliament and of the council of electricity produced from renewable energy sources.

The selection of turbine type and runner diameter was performed by use of nomogram method [2]. The propeller S turbine of 990 mm runner diameter was chosen. This turbine was designed, made, and mounted during the realization of project.

The design of turbine is based on the scaling of dimensions of 5 times smaller turbine. Estimated and measuring turbine characteristics are corresponding (fig. 4). From fig. 4, for summary efficiency 0.6 of system turbine – generator, electrical power of induction generator (estimated and measured) is 38 kW.

The MHPS power house is jointed to existing weir near to river bed.

The year energy which is given from MHPS in first phase (one turbine) is 280,000 kWh per year and in second phase is 500,000 kWh per year.

The ecological effect of constructed MHPS can be expressed by the coal economy and by the reduce of CO_2 emission. The economy of coal in first phase of MHPS is 340 t and in second phase is 607 t. Expected reduce of CO_2 emission in first phase is 349 t and in second phase is 623 t.

The energy efficiency of MHPS can be expressed by the reduce of power losses in distributive feeders and in transformers of low voltage grid. These reduces of power losses are 0.89 kW in first phase of MHPS and 1.89 kW in second phase.

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