# Optimization of the pipeline diameter for a small hydropower plant: case study

*Abstract*
The goal of the paper is to find the optimal diameter and penstock material for a small hydropower plant (SHPP) Kašići on the Jošanica river. The SHPP has nominal flowrate of 5.65 $m^3/s$, the head 37.76 m and the total penstock length 2950 m. The SHPP should be functioning as the second plant in a cascade system when the above SHPP Belci has extremely low flowrates, below 17% of the nominal. During these flowrates the existing turbine in the SHPP Belci has low efficiency, which is improved by bypassing SHPP Belci and implementing two turbines in the SHPP Kašići. One of these turbines is used for low flowrates during which maximal gauge static pressure in the penstock rises from 3.776 bar to 7.23 bar. Based on the known penstock layout and probability of the river flowrates, friction factors for different penstock materials, total pressure drop, and total electricity production were calculated. Steel, polyester (fiberglass), polyvinyl, and wood were the analyzed penstock materials. The net present value (NPV), which was calculated as the ratio between the profit from electricity selling and the penstock investment, was used as the selection criterion for optimal diameter. There are two optimal solutions with inner diameters of 1700 and 1800 mm, both made from polyester and steel in the lengths of 1550 m and 1400 m, respectively. The difference between the NPV's for two optimal solutions for the analyzed period of 12 years, during which guaranteed feed-in tariffs in the Republic of Serbia lasts, are less than 0.02%.

## 1. Introduction

The implementation of feed-in tariffs in Serbia [1] has led to the build-up of numerous electric and cogeneration facilities that use renewable energy sources. Micro and small hydropower plants (SHPP) have large share in these activities as 44 plants have been constructed [2]. The specific investment cost of these plants is in the range from 1000 to 2000 € per kW of installed power and depends on: water flow, the ratio between total head and the distance between water intake and power house, accessibility of the terrain, the composition of soil where buried pipelines are used, pipeline material, the type of water intake, the quality of installed equipment, conditions for the connection to the national power grid, and the cost of resolving property relations.
The goal of the paper is to find the optimal material and pipeline diameter for SHPP Kašići on the Jošanica river based on the given routing and flow-duration curve. This is a specific case but the performed analysis is general and could be implemented in every hydropower project. The SHPP Kašići has nominal flowrate of 5.65 $m^3/s$, head of 37.76 m and the total pipeline length of 2950 m. The SHPP should be functioning as the second plant in a cascade system. Figure 1-b shows the basic technical characteristics and the layout of this system. When the above SHPP Belci has extremely low flowrates, below 17% of the nominal, its existing crossflow turbine has very low efficiency (see Fig. 1-a)). This problem should be solved in the new SHPP Kašići by implementing two turbines, one of which would be used for low flow rates. During these flows, water should be bypassing SHPP Belci, which would be out of function, and as a consequence, the maximal gauge static pressure in the designed penstock would rise from 3.776 bar to 7.23 bar. It must be stressed that draughts, which have been causing low flow rates, have been very common and unusually long during the period 2011-2013 and 2015 (see [3]). The basic characteristics of different pipelines, the methodology for calculation