UTILIZATION OF MEASURING STAND FOR PICO-HYDROPOWER PLANTS

Jozef FIALA, Bohumil TARABA

Authors: ***Ing. Jozef Fiala, Ph.D.* [1]*, Assoc. Prof. Ing. Bohumil Taraba, Ph.D.* [2]**
Workplace: ***Slovak University of Technology in Bratislava,***
Faculty of Materials Science and Technology in Trnava,
[1]*Institute of Safety and Environmental Engineering*
[2]*Institute of Production Systems and Applied Mechanics*
Address: **[1] *Botanická 49 , 917 24 Trnava, Slovak Republic***
[2] *Rázusova 2, 917 24 Trnava, Slovak Republic*
E-mail: ***jozef.fiala@stuba.sk, bohumil.taraba@stuba.sk***

Abstract

Various parameters and characteristics of water turbines need to be tested in the phase of development prior to their implementation. This paper describes a measuring stand for water turbines testing. The small measuring stand includes a centrifugal water pump, a mechanical brake - to simulate load, digital torque meter, digital tachometer, flow meter, supporting structure, a slop tank and measuring and control equipment. This paper presents the individual equipment and devices and their utilization in the "Hybrid power source for technical consulting and laboratory use and promotion of renewable energy sources (ITMS 26220220056)" project.

Key words

Pico-hydropower plants, strengths and weaknesses of hydropower, measuring stand, measurement and control

Introduction

Renewable energy sources currently represent one of the main tools that contribute to achieving three fundamental objectives of EU energy policy - competitiveness, sustainable development and security of energy supply. Renewable energy sources have their limitations but they have also opened possibilities that are not used extensively.

It is well known that low flow rates and very low heads represent a great potential in the territory of most countries in the world. This potential energy is not applied in practice. Its use in recent years is necessary. New ways of using micro-potential of water are currently looking for so that it was technically and also economically efficient.

Using very small hydropower resources is one of the favourable application possibilities in this direction. Small hydropower resources allow the use of underutilized micro-parameters yet. Various parameters and characteristics of water turbines need to be tested in the development and before their implementation. This testing is performed on measuring stands. Small measuring stand for testing the basic parameters of water turbines is located at Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in

Trnava, Institute of Safety and Environmental Engineering. Small measuring stand simulates water flow conditions in the real environment.

Pico-hydropower plants

What is a small hydropower plant? There is no international consensus on the definition of small hydropower. The general tendency all over the world to define Small hydropower plants by Power output. Different countries are following different norms keeping the upper limit ranging from 5 to 50 MW, in Slovakia to 10 MW of installed capacity. Between the small hydropower plants are classified also Pico-hydropower plants in the Slovak legislation in the category of domestic power plants with installed capacity up to 35 kW [1]. Pico-hydro is a term used to describe the smallest systems, covering hydroelectric power generation under 5 kW. Depending on its size, a Pico-hydro power system may provide a small, remote community with adequate electricity to power light bulbs, radios, and televisions, among other appliances. Small hydropower plants are usually constructed as a run-of-river power station with no accumulation. They have no ability to regulate the flow and or performance and power generation in real time. Their operation is usually dependent on the instantaneous hydrologic conditions of the flow [2].

Strengths and weaknesses of hydropower

After more than a century of experience, hydropower's strengths and weaknesses have been equally well understood. Hydropower's negative impacts are well understood and, although not all of them can be eliminated, much can be done to mitigate them. Some strengths and weaknesses are shown in the following Tab. 1 [3].

HYDROPOWER STRENGTHS AND WEAKNESSES [3, 4 and 5]. Table 1

ADVANTAGES	DISADVANTAGES
Provides low operating and maintenance costs Provides long life span (50 to 100 years and more) Meets load flexibly (i.e. hydro with reservoir) Provides reliable service Includes proven technology Provides highest energy efficiency rate (payback ratio and conversion process) Creates employment opportunities Saves fuel Can provide energy independence by exploiting national resources Often provides flood protection May enhance navigation conditions Improves living conditions Produces no atmospheric pollutants Produces no waste Avoids depleting non-renewable fuel resources Can create new freshwater ecosystems with increased productivity	High upfront investment Precipitation dependent In some cases, the storage capacity of reservoirs may decrease due to sedimentation Requires long-term planning May involve resettlement May restrict navigation Effects on cultural heritage may need to be addressed Inundation of terrestrial habitat Modification of hydrological regimes Modification of aquatic habitats Barriers for fish migration, fish entrainment Sediment composition and transport may need to be monitored/managed

Measuring stand for Pico-hydropower plants

In the workplace, there is a small measuring stand for testing the basic parameters for Pico-hydro turbines, which simulates water flow conditions in the real environment. The small measuring stand includes a centrifugal water pump, a mechanical brake - to simulate load, digital torque meter, digital tachometer, flow meter, supporting structure, a slop tank and measuring and control equipment. . Used information is available in the literature [6,7and 8]. The measuring stand is shown in Fig. 1.

***Figure 1** Measuring stand for Pico-hydropower plants [Photo by authors]*
1 - water pump, 2 - mechanical brake, 3 - digital torque meter with digital tachometer, 4 - flow meter, 5 - Supporting structure and collecting tank, 6 - measuring and control equipment, 7 - water pump protection, 8 – experimental water turbine

Water pump

Pumping circuit includes CM 10-2 ARAVIS - AQQV centrifugal pump Grundfos. Nominal pump flow is 10 m^3/h and the delivery head is 27.1 m. The pump speed is controlled by frequency inverter. To achieve the minimum flow, a control valve is included into the discharge pipe located behind the pump. The valve is designed for the protection of the pump - for more fluent control of mass flow rate, respectively to protect the pump from destruction at low speeds. If necessary, the flow can be regulated by manual control valve.

Flow meter

To measure the flow, HRI - Pulse A1/D1 flow meter with pulse output is used. The flow meter captures the instantaneous flow rate. Control system converts the mass flow rate based on this data.

Supporting structure and collecting tank

The supporting structure is made of steel profiles. The construction consists of two separate parts:

- separate construction for a collecting tank,
- separate construction for devices (water pump, fittings, measuring and control equipment, etc.).

Plastic collecting tank by the volume of 288 l is inserted into the structure. There are two openings. Drain valve is installed in the bottom openings. Through a side opening, the tank is connected to the suction line.

Water pump protection

If all the fittings on the pumping circuit will remain closed and the system is put into operation, KP35 pressure switch is placed in the pipe. Pressure switch is set up to 3 bar. Pumping circuit is shut down when the pressure is increased. The circuit is put into operation again when the pressure is reduced.

Measurement and control

RCO 721D-W digital controller with extension module RCO 210D-S is designed to manage regulation . Control is provided by a free programmable microprocessor controller. Actuators and individual devices are controlled by output signals. The controller contains a real-time module. Memory of the regulator is backed up against the data loss when power outage. The controller includes a display and the components which are designed for manual intervention to control [6]. This allows you to monitor all parameters and manually control outputs of the regulator to the basic operational level. The controller is equipped with an Ethernet connection and Web server.

The control system reads the pulses from the flow meter. Based on this data, the control system converts the mass flow rate. Pulse output of water meter is connected to the control system via digital input modules. The control system also controls the flow in the system through the control valve and through a frequency inverter.

Digital torque meter

The Lorenz DR 3000 USB torque sensor measures torque speed and angle with a direct connection to a PC or other device with a USB interface. This sensor has a contactless and digital signal transmission from rotor to stator, which means no signal falsification and maintenance-free. Range of the Lorenz DR 3000 USB Torque Sensor is from 0.5 to 5 N/m, shaft speeds for the lower torque ranges are up to 30,000 rpm, measurement rates are up to 2500 samples/second, and the resolution of the output signal is 16 bit.

Digital tachometer

Lutron DT-2230 photo/contact tachometer uses a laser light detecting source, long measuring range up to 1.5 meters. It is useful in the rpm measurement application where the machine would be at risk to the operator or close access is difficult or impossible. Wide measuring ranges from 0.5 to 100,000 rpm, 0.1 rpm resolution for the measured value < 1000 rpm.

Basic operation

Measuring stand for Pico-hydropower plants can be operated manually or automatically, according to the requirements of the operator. Management is performed via the control system panel in a door of switchboard (Fig. 2) or through the connected PC station (Fig.3). The processes and states of connected devices are managed controlled and changed via the web interface using PC. Turning on/off is operated by the main switch located at the side of the switchboard [7].

Figure. 2 *Control system panel in the door of switchboard [Photo by authors]*

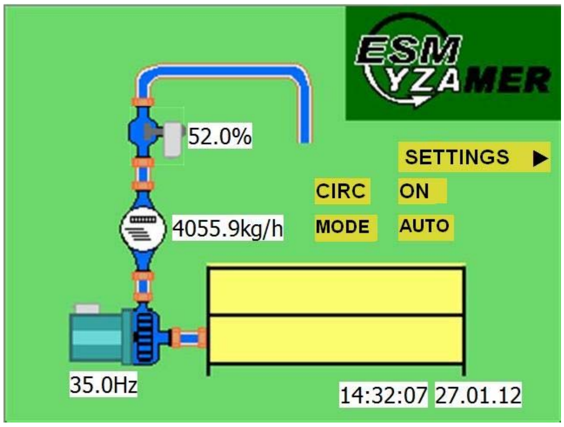

Figure 3 *Control by PC [Photo by authors]*

CIRC – Circulation (ON-OFF), MODE (AUTO – MANUAL)

Automatic mode

For automatic regulation, it is necessary to choose an automatic mode in the main menu in section "REŽIM (MODE) → AUTO "(Fig. 3). In the section "NASTAVENIE (SETTINGS)", it is necessary to choose the requested flow rate ("Ziadany prietok ="). The flow rate can be changed from 3000 kg/h to 6,500 kg/h (Fig. 4). Settings of the requested flow rate can be increased or decreased by 50 kg/h.

If the automatic mode is selected and the requested flow rate is set up, the circulation of the water will start with selecting an item in the main menu "OBEH (CIRCULATION) → ZAP (ON)". After starting the circulation, the controller waits 80 second. During the 80 seconds, the control valve is open to the value calculated by the controller according to the set flow rate. After 80 seconds, the frequency is set and the water pump starts operating. The controller measures the instantaneous flow. Then the flow rate is calculated and controlled. If the requested flow rate is changed, the controller calculates the requested frequency while slightly opening of the control valve. Stabilization of required flow takes about 1-2 minutes. Permanent control deviation occurs in the regulation.

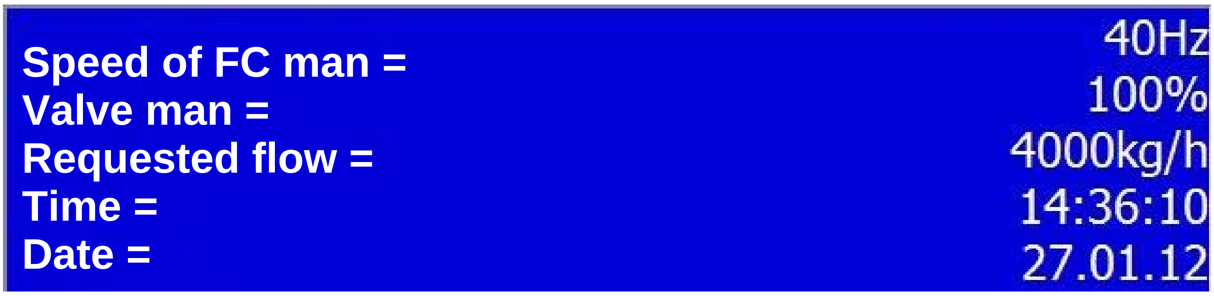

Figure 4 Settings for manual and automatic modes *[Photo by authors]*
Manual mode – speed of frequency converter, opening and closing valve
Automatic mode - change of the requested flow

Manual mode

For manual regulation, it is necessary to choose a manual mode in the main menu, section "REŽIM (MODE) → RUC (MANUAL)"(Fig. 3) [8]. By changing the frequency range from 35 to 50 Hz, or by throttling valve in range from 30 to 100% (Fig. 4), it is possible to change the flow which can be set up in the section "NASTAVENIE (SETTINGS)". Circulation of the water will start by selecting an item in the main menu "OBEH (CIRCULATION) → ZAP (ON)" if required parameters are set up.

Determination of basic parameters of water turbines

The size of power P_h is defined of the basic parameters of the hydro turbine (flow Q, water head H). This power expresses the size of the hydraulic turbine output. Usually it is described as theoretical power [9], with conversion efficiency η = 1, i.e. 100% [10].

This theoretical power represents the input power entered into a water turbine and is called the input power P_h in relation to the turbine [11]:

$$P_h = g \cdot Q \cdot H \quad , \tag{1}$$

where
P_h is theoretical power, respectively input power in [W],
g is gravitational acceleration in [m/s^2],
Q is water flow in [kg/s],
H is water head in [m].

To determine the actual output power of the water turbine it is necessary to define the torque of the shaft of the turbine [11]. In rotational systems, power is the product of the torque τ and angular frequency ω,

$$P_t = \tau \cdot \omega , \tag{2}$$

where

P_t is actual output power of the water turbine in [W],
τ is torque in [Nm],

ω is angular frequency in [s^{-1}].

$$\omega = \frac{2 \cdot \pi}{T} \;, \tag{3}$$

where
T is the period in [s],

then

$$P_t = \frac{2 \cdot \pi \cdot n \cdot \tau}{T}, \tag{4}$$

where
n/T are revolutions per second in [s^{-1}].

Ratio of input to output power represents the efficiency η in [%] of the water turbine:

$$\eta = \frac{P_t}{P_h} \cdot 100 \,. \tag{5}$$

Conclusion

Small hydropower plants cannot significantly contribute to the development of power system. However, small hydropower plants are properly utilised in the orientation of the environmental aspects of energy policy with regard to clean energy sources and high energy efficiency programme. The pre-requisite for the development of small hydro power plants is their low start-up and operating costs. This requires a focus on the simplest possible construction, machinery and electrical equipment. Testing parameters of water turbines are very important in the development and selection of suitable water turbines. Experimental test station for water turbines designed at the Institute of Safety and Environmental Engineering, MTF STU in Trnava within the project “Hybrid power source for technical consulting and laboratory use and promotion of renewable energy sources "(ITMS 26220220056)” can help in testing the basic parameters of water turbines. It contains all necessary equipment and facilities to determine the parameters of power and efficiency of water turbines in different conditions of water flow. The paper presents the actual construction of the measuring device and its utilization. In terms of promotional, it is expected to address a selected group for potential co-operation in research and development of small hydro turbines and testing their basic parameters. Currently, the function of individual components of the measuring and control equipment is controlled by measuring all components of the measurement device and the accuracy of the connection. Based on results, it will be necessary to ensure regulation and optimization of individual components so that the device will be capable of long-term testing of small hydro turbines. Currently, the basic parameters of a patented water turbine prototype are being tested. In the long term horizon, will also be used for promotional purposes for high school students, the purposes of bachelor theses at universities, or as a part of a counselling centre for renewable energy sources.

Thanks to the company of **ESM YZAMER, Energy Services and monitoring Ltd.** for the preparing technical documentation and construction of the measuring stand for Pico-hydropower plants.

This paper was written with the support of the Research and Development Operational Programme within the project: "Hybrid power source for technical and consulting laboratory use and promotion of renewable energy sources" (ITMS 26220220056), financed from the resources of the European Regional Development Fund.

References:

1. STN 75 0128: 1988 Water management. Nomenclature of water power utilization
2. BROŽA, V., SATRAPA, L. Hydrotechnical constructions *1*. Prague: ČVUT, 2007. 170 p. ISBN 978-80-01-03653-2
3. Sustainable hydropower. *About Sustainability in the Hydropower Industry.* [online]. [cit. 2012-01-15]. Available at <: http://www.sustainablehydropower.org/site/siteresource_pages/sustainabilityindustry.pdf >
4. DUŠIČKA, P., HODÁK, T., ŠULEK, P. *The use of primary hydropower potential in Slovakia*. In *TZB HAUSTECHNIK,* 2008, No. 5.
5. HODÁK, T., DUŠIČKA, P. *Problems of utilization of the primary HEP in Slovakia*. In: *Hydroturbo 2004 : 17.* International Conference. Brno: VUT, 2004.
6. Small hydropower source - implementation documentation. Measurement and control. ESM YZAMER, 2011, internal document
7. Small hydropower source - real execution. Technology. ESM YZAMER, 2011, internal document
8. Small hydropower source - control system. User guide. ESM YZAMER, 2011, internal document
9. VILEM, J., *Designing hydroelectric power plants.* Bratislava : STU Bratislava, 2001. 223 p. ISBN 80-227-1468-2
10. MASTNÝ P. *Small sources of electricity – hydropower.* UEEN VUT FEKT Brno [online]. [cit. 2012-02-23]. Available at <: *http://www.ueen.feec.vutbr.cz/~mastny/vyuka/mmze/skripta/voda.pdf* >
11. HOSTIN, S., et al. Small hydroelectric power plant – final report. Aqua energy association, Project PHARE 95/0401, Bratislava

Reviewers:

Peter Horbaj, Professor, Ph.D. – Faculty of Mechanical Engineering, Technical University of Košice

Mikuláš Monoši, Assoc. Professor, Ph.D. – Faculty of Special Engineering, University of Žilina