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LABORATORY STAND WITH MICRO HYDRO GENERATOR

SUSANA ARAD[1], LILIANA SAMOILA[2], ION SARDAROIU[3]

Abstract: Hydroelectric power is not only renewable but also green energy. The force of the falling water sets the turbines in motion to produce electricity. The water is collected in an accumulation lake and channels through a dam. The conditions for hydroelectric power are: a strong and fast current of water and a significant height of water fall. The paper aims at a study on hydraulic energy, especially on micro hydropower plants and the achievement of a laboratory stand for student use.

Keywords: hydro generator, Pelton turbine, permanent magnet generator, laboratory stand

1. GENERAL ASPECTS

Major changes have taken place in the energy sector in most European countries due to the need to increase security in the supply of energy to consumers, and within this requirement renewable energy sources offer a viable solution, including environmental protection [1].

Hydroelectric power is not only renewable, but also clean. It does not produce waste, does not produce carbon dioxide that contributes to the greenhouse effect and does not produce sulfur oxides that are the source of acid rain.

The objectives regarding the capitalization of renewable energy sources in Romania consist in [3], [5], [9]:

• integration of renewable sources in the structure of the national power system (based on conventional resources);

• elimination of technical-functional and psycho-social barriers from the process of capitalization of renewable energy sources and framing within the limits of cost elements and economic efficiency;

[1] *Professor Eng., Ph.D. at the University of Petrosani, susanaarad@yahoo.com*
[2] *Assoc. Professor Eng., Ph.D. at the University of Petrosani, branaliliana@gmail.com*
[3] *MSC Student University of Petrosani, eyeless18@yahoo.com*

- promoting private investments and creating the conditions to facilitate the access of foreign capital on the renewable sources market;
- diminishing the degree of dependence of the national economy on primary energy imports;
- ensuring energy supply in isolated communities by capitalizing on the potential of local energy resources;
- ensuring the conditions for Romania's participation in the European market of "Green Certificates" for energy from renewable sources.

Hydraulic energy is actually a potential mechanical or kinetic energy. The exploitation of this energy is done in hydropower plants and power plants that produce electricity based on water energy (tidal and wave energy). The use of water has been known for thousands of years. For over two thousand years, water has been used in many parts of the world, especially for grinding grain and producing energy.

2. HYDRAULIC ENERGY - STRUCTURE OF HYDRO ENERGY SYSTEMS

The force of the falling water sets the turbines in motion to produce electricity. The water is collected in an accumulation lake and channels through a dam. The conditions for hydroelectric power are: a strong and fast current of water and a significant height of water fall.

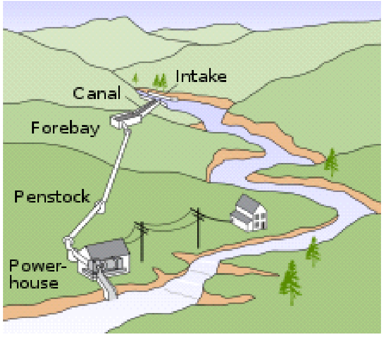
In Romania, the hydropower potential of the main rivers is high, used in high power and low power (less than 10 MW / hydro unit) hydroelectric schemes. [10]

The classification of hydro energy sources may have the following representation: [15]

- high power schemes (34,000 GWh/year);
- medium power schemes (6,000 GWh/year)
- low power schemes which are classified as follows:
  - hydroelectric units with higher power than 3,600 kW;
  - hydroelectric units with power below 3,600 kW, differentiated into three subcategories: (i) low power hydroelectric units, with installed power between 200 kW and 3,600 kW; (ii) micro hydropower plants, with an installed capacity between 20 kW and 200 kW; (iii) artisanal hydroelectric units with an installed capacity of less than 20 kW. [15]

The main civil works for the arrangement of a hydroelectric power plant consist in: dam or penstock, pipes for transferring the water and the building of the power plant (powerhouse). The main components of a hydropower scheme are shown in Fig. 1 [7]:

- reservoir - the enclosure on the river in which the water of the river accumulates;
- dam of different types, which blocks the river valley for water accumulation;
- powerhouse where turbines and electric generator are found;
- spillway tunnel, through which water is evacuated, after machining through turbines.



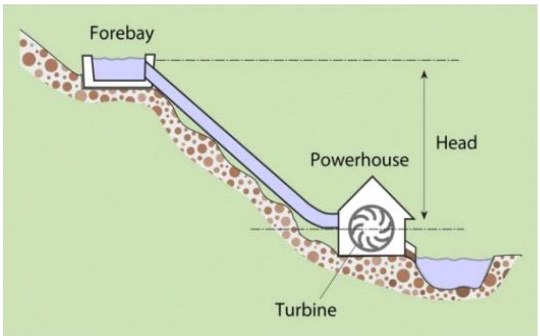


Fig. 1. Hydropower facilities

To build a system of micro hydropower plants, we need access to running water on the property. Sufficient falling water must be available, which usually, but not always, means that the best sites are the hilly or mountainous ones as the best. Other considerations for a potential location of micro hydropower plants include: energy production, economy, permits and water rights.

Most power plants initially need a form of mechanical power that rotates the generator to produce electricity. In the case of hydroelectricity, mechanical energy comes from the fall of large volumes of water. For a long time, the easiest way to produce the fall of water needed to produce electricity was to build a dam.

This resource is renewable and does not generate carbon emissions. [1]

Micro and pico hydropower plants can be built on small watercourses and are a solution for providing electricity in small and isolated settlements or individual consumers. [1]

The amount of energy generated when a a body descends with a height difference in the gravitational field is:

$$E=mgh \tag{1}$$

where: g is the gravitational acceleration, m - water mass and h - fall height.

The hydraulic energy available in a reservoir can be extracted by intentionally lowering the water level. In this case, the power depends on the water mass flow rate:

$$\frac{E}{t} = \frac{m}{t} \cdot g \cdot h \tag{2}$$

Since the E/t is actually the power itself and expressing the fraction m/t in the right member depending on the volume flow rate ϕ and water density ρ, the usual relation is:

$$P = \rho \phi g h \tag{3}$$

To obtain the power P in watts, ρ must be given in kg/m^3, ϕ - in m^3/s, g – in m/s^2 and h in m.

Hydropower is certainly the most widespread and most mature application of renewable energy. 22% of the world's electricity production comes from hydropower plants, many of which are low-power hydro plants that produce less than 10 MW; there are more than 17,400 such powerplants in Europe [11]. Hydropower is an important part of the world's primary energy resources, the use of which is essential to ensure coverage of ever-increasing energy consumption in all countries.

3. ENERGY SIZING OF MICRO HYDROPOWER PLANTS

Conventional hydraulic energy is the energy related to rivers and streams, generally called hydro energy. The level difference between the elevation of a section from which water falls (flows) and the elevation of the section to which water reaches gives the measure of potential energy. This energy is converted into kinetic energy.

Hydraulic energy resources are continuously regenerated by the transformation and natural accumulation of solar energy. The primary source of hydraulic energy is solar radiation and the water circuit in nature. Solar radiation causes evaporation (especially from the planet's ocean), clouds laden with water vapor move over land, under certain conditions condense, precipitation falls on the land surface and part of the water volume forms surface runoff. Based on these considerations, it is clear that hydro energy is renewable.

The micro-hydropower plants are low-power hydroelectric plants, which capitalize on the hydraulic energy of a river sector, without changing its flow regime. According to the operation mode, the hydropower plant uses only the water available from the natural flow of the river.

The hydraulic scheme of a micro hydropower plant consists in the following parts (fig. 1) [7]:

- Water intake with grate for floating objects that could affect the integrity of the turbine.
- A gate and an entrance in a canal, a penstock or directly into the turbine, depending on the type of the scheme.

The powerhouse contains the turbine or turbines and most of the mechanical and electrical equipment. The buildings of the micro-hydropower plant are usually low sized with a strong foundation and access for maintenance and safety.

The capitalization of the primary hydraulic energy as hydroelectric energy is done through hydraulic turbines and electric generators. The water flows through the turbine blades and is set in rotational motion, the hydraulic energy turning into mechanical energy. The power of a hydropower plant depends on the water fall head but also on the machined water flow.

In order to decide whether it is feasible to build a micro-hydropower plant in a given river sector, the available water resource must first be rated.

The energy potential of the scheme is proportional to the product of the flow and the head [7]:

$$P = 9{,}81 \cdot \varepsilon \cdot Q_m \cdot \eta_G . H_{br} \tag{4}$$

$$P_i = 9{,}81 . Q_i . \eta_G . H_{br} \tag{5}$$

where:

P - useful hydroelectric power;

P_i - installed power in the micro hydro plant;

ε - the flow utilization coefficient taking into account discharges and flows that cannot be intaken for turbinating;

H_{br} - gross head along the sector;

η_G - - the overall efficiency given by the product of the efficiencies: the turbine efficiency, the generator efficiency, the hydraulic efficiency;

The energy dimensioning considers the determination of the installed flow Qi, the setting of the flow areas for the hydraulic circuit and the choice of the plant installed power [12], [13].

The type, geometry and dimensions of a turbine are determined by the net head, the range of turbinated flows and the turbine speed, with cavitation and cost as additional criteria. The most used types of hydraulic turbines are: Pelton, Francis and Kaplan.

After establishing the installed flow, the type of turbine is chosen, depending on the nominal flow and the head. The choice is made based on the graphs that define the operating ranges of the various type of turbines.

The main mechanical and electrical equipment of a micro hydropower plant are the turbine and the generator. The turbine rotates the generator rotor in the magnetic field of the stator and through the phenomenon of electromagnetic induction the mechanical energy is converted into electrical energy (fig. 2). The conversion of hydraulic energy into electricity is done with very good efficiency, which contributes to the economic yield of its use. [2]

There are two types of generators used in micro hydropower plants, namely synchronous and induction (asynchronous). A synchronous generator can be operated in isolation while an induction generator must be operated connected in the network. The efficiency of asynchronous generators is 2 - 4% lower than that of synchronous generators and as a result, they are chosen only for powers below 5000 kVA. The working voltage of the generators varies with power [4]. The usual voltage values are 380 or 430 V for power up to 1400 kVA and 6000 V for high installed power. However, high voltages require an independent transformer to supply the plant [7].

If the turbine and the generator have the same speed, the coupling of the turbine shaft is done directly with the shaft of the generator rotor. The coupling system is set by the equipment supplier, and a flexible coupling is recommended, which can accommodate any misalignments. However, there are many situations when the turbine speed is less than 400 rot/min. Because the standard generators have a speed of (1000-1500) rot/min, it is necessary to insert a speed multiplier between the turbine and the generator. The solution is more convenient than making a special generator, which would have high costs. [9]

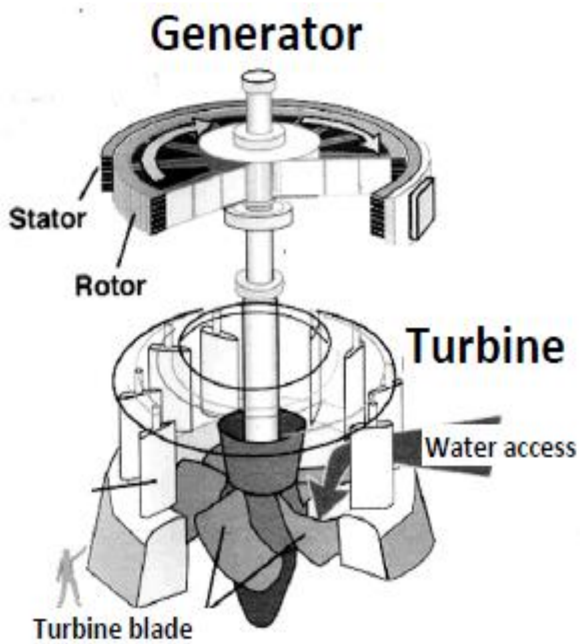


Fig. 2. Conversion of hydraulic energy into electricity

4. CONSTRUCTION OF THE STAND WITH MICRO HYDRO GENERATOR

We set out to build a small-scale but functional hydraulic system for teaching purposes, which consists of a turbine and a generator with permanent magnets. The turbine rotates due to high-intensity water jets obtained by feeding the system by a water source

To carry out this project we needed a Pelton turbine, a wheel enclosed in a vessel, a generator with permanent magnets and a hydrophore to ensure the water flow.

The first and most complex work was to make the turbine according to the Pelton turbine model. It was very difficult to manufacture the turbine blades [7]. The turbine was made by multiple tests. So, we obtained an optimal variant, as solid as possible, of the blades made of metallic material, which were welded (Fig. 3). Further, the turbine shaft was fixed in the middle of the housing whose front was closed by a transparent plexiglass cover, just to observe the operation of the equipment.

Fig. 3 Turbine construction

To obtain water under pressure we used a hydrophore that we bought, with which it was possible to adjust the water pressure as well as the flow in the turbine housing. The hydrophore we used has a power of 750 W, with a maximum absorption height of 9 m and a maximum discharge height of 30 m (3 atm.).

The turbine starts to operate when the injectors mounted on the housing feed pressurized water (Fig. 4) [8].

Fig. 4. Turbine housing and operation

The generator we used is Honda 100 W / 12 V with a speed of 500 rot/min. The assembly of the generator is shown in Fig. 5 [6], [8]. The stator coils are made of copper wire with a diameter of 1 mm and the rotor is equipped with permanent magnets. The rotor motion in the magnetic field generates an induced voltage within the coils.

Fig. 5. View of the generator with permanent magnets

The operating principle diagram of the assembly is shown in Fig. 6. [8] The components used to manufacture the appliance were: hydrophore (water pump, expansion vessel and pressure switch), handcrafted Pelton turbine, turbine housing, water injectors, connecting shaft between turbine and generator, dynamo with permanent magnets, voltmeter and electrical installation (bulbs and switches).

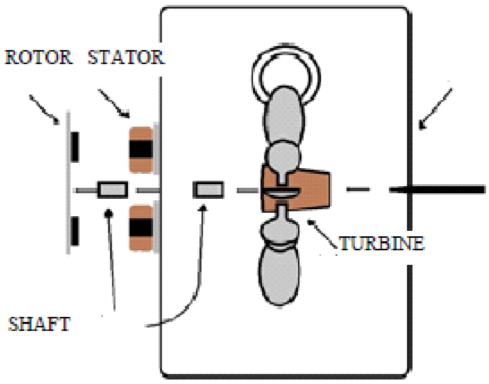


Fig. 6. Operating principle

The manufactured stand, after assembling and making the operation test, are shown in Figure 7. [8]

Fig. 7. Laboratory stand

After the realization of this project, we analyzed the situation in which a real system with turbine and generator would be built on an industrial scale so as to produce an adequate power so that it could be used to supply a cottage or isolated houses. This situation must be taken into account when the building cannot be connected to the electricity grid but has a water source nearby capable of providing both flow and head to operate this system of electricity production.

5. CONCLUSIONS

The proposed project addresses issues related to the power supply solutions of residential and tertiary consumers by using the technologies of Pelton turbine-based macro generation systems.

The potential energy of water is converted by a turbine into mechanical rotational energy. A jet of water at very high speed strikes the cups mounted on the rotor and imprints the rotational motion.

Among the components of a hydropower plant, the turbine is the basic component in energy production. Because it represents a major part of the cost of the installation and defines the return on investment, the turbine must be as efficient as possible in relation to its cost.

Starting from the idea of building a micro laboratory hydro generator, we designed and built a stand for teaching use.

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