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Small Hydropower Plants - As Renewable Energy Resources

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Abstract: With request of sustainable energy sources and technology advances, the hydro energy technology has a tendency of expansion. Nowadays the new sustainable technologies of power generation are highly desirable, including new hydro power stations. Those stations could contribute to promotion of green electricity, which is one of the new targets of energy policy of European Commission’s. With the purpose of evaluation and estimation of possibility to create a one monolithic hydro-electrical power system, consisting of small hydro stations a database of Lithuanians dams was developed. Database allows find each existing pond of Lithuania and calculate a potential power of it. Also the article deals with financial analysis of hydro energy projects. The specific of small hydropower plants projects (SHPP) is defined and the methodology for financial analysis of SHPP projects is presented. The methodology of risk assessments for the investments in SHPP is also presented in the article.
Key words: Hydropower plant, small hydropower plant, “green” energy, discharge.

INTRODUCTION

Hydropower is the kinetic energy of flowing water. When captured it can be used to power machinery or converted to electricity. Typically, hydropower plants dam a river or stream to store water in a reservoir. When the water is released from the reservoir, it flows through a turbine that causes it to spin and activates a generator to produce electricity. Plants that do not require dams may channel a portion of a river or stream through a small channel (Vaideliene A., 2007) that contains a turbine, or they may pump water to a holding area from where it can be released to generate electricity.

Today's hydropower plants range in size from small, local projects that produce several hundred kilowatts to huge dams and reservoirs that generate 10,000 MW or more and supply energy to millions of people. Hydropower provides a relatively low-cost, renewable source of electricity, and it does not discharge pollutants into the environment.

Unlike fossil fuel technology, hydropower uses a fuel — water — that is not consumed or depleted in the process. Although there is variation in the amount of flowing water, overall this is an endless, constantly recharging system.

The amount of hydropower resource varies widely among states. To have a viable hydropower resource, a state must have both a large volume of water and a significant change in elevation. For large amounts of electricity to be generated, huge volumes of water must drop from one elevation to a lower one. Thus, mountainous regions with rushing rivers offer the best potential for hydropower projects.

There are different categories of hydropower facilities: impoundment hydropower, diversion (or "run of the river") hydropower, and pumped storage hydropower. A few are built by private utilities for commercial use. Many are part of a multipurpose project. That is, in addition to producing electricity, they provide for flood control, water supply, irrigation, transportation and recreation.

Other sources of hydropower involve ocean waves or tidal changes to generate electricity. These technologies are not as well developed as the more conventional hydropower sources.

With request of sustainable energy sources and technology advances, the hydro energy technology has a tendency of expansion. Nowadays the new sustainable technologies of power generation are highly desirable, including new hydro power stations. Those stations could contribute to promotion of green electricity, which is one of the new targets of energy policy of European Commission's (Commission of the European Communities, 2000).

With the purpose of evaluation and estimation of possibility to create a one monolithic hydro-electrical power system, consisting of small hydro stations a database of Lithuanians dams was developed. Database allows find each existing pond of Lithuania and calculate a potential power of it. Also the article deals with financial analysis of hydro energy projects. The specific of small hydro power plants projects (SHPP) is defined and the methodology for financial analysis of SHPP projects is presented. The methodology of risk assessments for the investments in SHPP is also presented in the article.

WATER WHEEL and THE FIRSTS HYDROPOWER PLANTS

The history of usage of falling water energy has deep roots in Lithuania. The first water mill in Lithuania was built in 1256. Till the end of 19th century, when usage of hydro energy started to be replaced by thermal energy, the hydro and wind energy were only energy sources used for mills driving. Therefore in Lithuania were build many dams, that later were neglected, plants destroyed or collapsed, but their dams at many places were survived till our days.

The greatest event in the history of humanity was the invention of water wheel that is comparable to the invention of wheel itself. The water wheel has the longest history of serving people as a hydro technical devise converting the mechanical water flow energy to rotational one. It had been used in Europe since the first century. Only in 1817 K. von Drais the German inventor proposed the improved water wheel – the water turbine wheel. The first active force water turbine was made in 1750 by J. Zegner in Hungary. Later, in 1817 B. Furneron in France invented the reactive water turbine and famous scientist L. Euler for the first time presented fundamentals of the theory of water turbine. In Lithuania the replacement of water wheels by the water turbines in mills and other power facilities has begun in the end of 19th century. Paradoxically many of water wheels survived until the middle of twentieth century. Nowadays water wheels cannot to be found in the power plant. The first small hydropower plant (SHPP) in Lithuania was built in 1900.

The second SHPP, which was producing only electricity power, had been mounted at the beginning of this twenties century (1910) on the river Sventoji in Anyksciai. Two hydro turbines there rotated generators which capacity was 280 kW. The others were begun to build only after World War I. In such a way hydropower plants in 1924 on the river Minija in Stonaiciai had capacity of 130 kW. The most interesting of them may be considered the one in Grigiskes where at first the so-called small derivation hydropower plant of 90 kW capacities was built in 1925, later, in 1930 – a greater derivation of 450 kW capacities.

Now in Lithuania are 84 small hydropower plants.

MATERIAL and METHOD

According the kind of motion water energy can be treated as mechanical energy. As known, mechanical energy can be potential and kinetic. The water as well as any other liquid can generate the energy of both kinds. Because the potential energy E_p is the product of water masses and kinetic energy E_k depends on velocity of water masses, the both energies plays substantial role for the generation of electricity. Therefore initial power is potential power (Vaideliene A., Kadisa S., Glemziene R., 2006) and final power is the kinetic power in the process of the generation electricity on hydropower stations. So, the rivers power is the most suitable source for transformation hydro energy to the electricity.

The mechanical energy of water flow consists of potential and kinetic energy that generates the forces of water weight and inertia.

The potential energy E_p (Vaideliene A., 2001) of falling water can be expressed trough the force *mg* of water mass *m*, acting on distance *H,* as follow:

$$E_p = mgH(J) \qquad (1)$$

The mass of water *m* can be expressed as product of volume *V* (m³) and its density ρ (1000 kg/m³): $m = V \cdot \rho$ (kg).

Suppose, that the water of volume *V*, flowed per one second is a discharge *Q* (m³/s), g = 9,81 (m/s^2) is a free fallow acceleration and the power, i.e. potential energy per second, is P_p. Then the power can be written as:

$$P_p = \rho\ g\ Q\ H = 1000 \cdot 9{,}81\ Q\ H = 9{,}81\ QH \text{ (kW)}. \quad (2)$$

The kinetic energy E_k of falling water is equal to half of product of water mass *m* (kg) and square of velocity of water mass, i.e.:

$$E_t = \frac{1}{2} m \cdot v \quad (3)$$

With the mass, expressed through its density and the volume trough debit *Q*, can be obtained kinetic energy per second or kinetic power P_k:

$$P_k = \frac{\rho \cdot Q \cdot v^2}{2} = \frac{1000 \cdot Q \cdot v^2}{2} 0{,}5 \cdot Q \cdot v^2\ (kW) \quad (4)$$

The formulas above shows, that potential hydro energy is stimulated by water mass weight force (*mg*) and its fallow height (*H*) and the kinetic hydro energy by value of water mass flow (discharge) and the velocity of this flow. The latest one mentioned energy isn't used in the hydro energetic due to its not enough high velocities of water flows though sometimes it occurs as force major in the nature. Though the air kinetic energy is widely used in the wind energetic, because the air density is low and its velocity is high enough.

Resources of potential hydro energy (Vaideliene A., 2005), based on rivers discharge cadastre data theoretically may be estimated as:

$$P = 9{,}81 \cdot \frac{Q_1 + Q_2}{2} \cdot H \quad (5)$$

$$E = P \cdot t\ \ (kWh) \quad (6)$$

were *P* is a potential power; *E* – potential hydro energy; Q_1 and Q_2 – accordingly initial and final water discharge (m³/s) on rivers investigated dam; *H* – fall of water level (*m*); *t* – time (h) during which the hydro energy (kWh) were produced.

According formula (6) determined hydro energy is so called nature or cadastre hydro energy. Real or technical hydro energy is less as nature hydro energy due to water pressure and discharge losses, also due to efficiency of hydro aggregate (usually equal to about η= 0,815 [2]) (Figure 1).

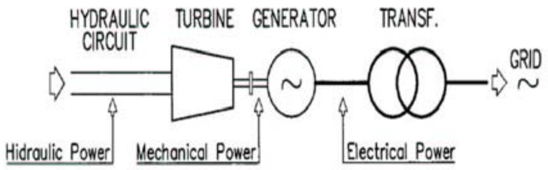

Figure 1. Power conversion scheme.

RESULTS AND DISCUSION

Hydropower is the most important energy source in what concerns no carbons dioxide, sulphur dioxide, nitrous oxides or any other type of air emissions and no solid or liquid wastes production. The introduction of innovative solutions coupled to renewable energy (Fig. 1) technologies should contribute to a substantial global reduction in emission of CO_2 and other gases (Vaideliene A., 2007).

At the moment the main part of "green" electricity power produced consist of hydro energy. 2004 all amount of electricity energy, consisting of 420.5 GWh was produced by hydro power stations, what makes 98 % of all "green" energy produced at this year.

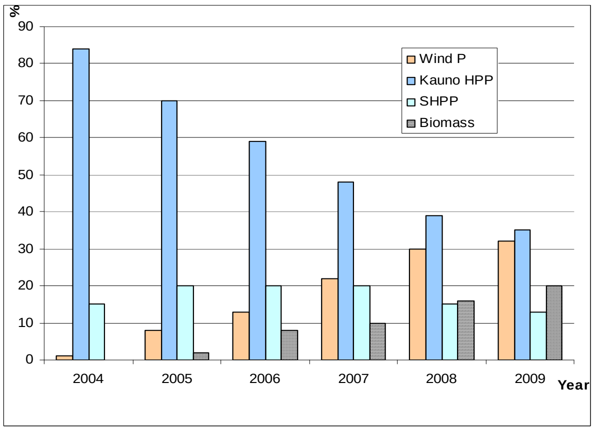

Figure 2. Production of "green" electricity energy in Lithuania.

The greatest producer of hydropower energy is Kaunas Hydro Power Station (100.8 MW). Last year 359 GWh electricity energy was produced at this station. On the other hand amount of hydro energy produced at small (less as 10 MW) hydro plants is permanently growing (Fig. 3). 2004 approximately 61.5 GWh was produced at small hydro plants, what makes 50 % greater amount in comparing whit the 2003. Estimated amount of energy produced at Kaunas hydro plant till 2010 is 330 GWh per year.

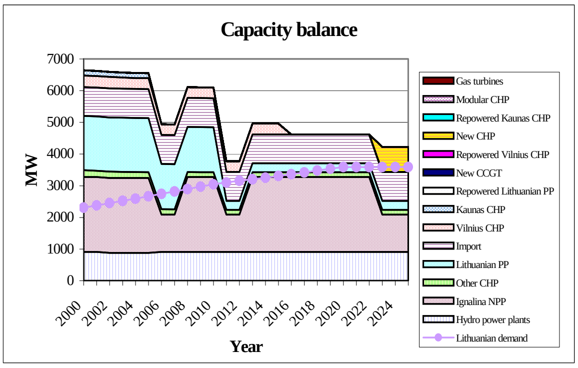

Figure 3. Estimated balance of capacity.

The vast dimensions scheme of using hydro energy is limited by Environmental law of Lithuanian Republic.

CONCLUSIONS

1. Hydro energy is local renewable and clean electricity generation source and one of main renewable energy resources in Lithuania.
2. Hydro energy is not only commercial business this also an improved landscape, arranged infrastructure, improved recreational conditions, created conditions for fish-ladder, tourism and other branches of water economy.
3. The computerized Database of Lithuanians dams allow quick and user-friendly search of selected dam according name, region, and basin as well as calculate needed characteristics. All wanted information appears on screen of computer in seconds. The architecture of Database allows update it very easy.

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