

HYDRAULIC ACTUATION SPECIFIC TO MICRO HYDROPOWER PLANTS

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Abstract: *Being the oldest renewable energy, hydropower is and will remain the most important source used. The paper deals with the Micro Hydropower plants with medium or high head, it presents the particularities and the problematic of the fluid power systems used to operate the hydromechanical equipment, specific to this particular hydro-technical constructions. The problems at these types of systems are related to: energy efficiency and synchronization of the movement when using cylinders in pairs at one single gate (radial or sluice). Operating the hydromechanical equipment specific to MHPs, using fluid power systems, in the opinion of authors, remains the most convenient option. Finally the paper outlines several solutions to optimize these specific systems.*

Keywords: *micro hydropower, hydrostatic actuation, hydromechanical equipment.*

1. Introduction

Currently, the global energy generated from hydropower reach about 2.1 million GWh, annually, which represents 16%...18% of worldwide electricity consumption. The most pessimistic estimates accepts that exploitable potential is six times higher. At European level, hydropower produces over 85% of renewable energy. In Romania, are produced annually, on average, about 18 TWh, 35% of consumption, but the potential is 38 TWh/year [1].

The term Micro Hydropower (MHP), will be used in this paper and it will imply a plant with an installed power of 100 kW to 5 MW.

Hydroelectric energy is not only renewable is also clean. It does not produce: waste (ash or radioactive substances); carbon dioxide that contribute to the greenhouse effect or sulphur oxides which underlying the acid rain. Its fuel is water, a clean fuel that does not undergo degradation [1].

Lately, in Romania, it was manifested a great demand of authorizations for micro hydropower plants, due to the advantages they have but also because there is still a great potential to exploit the hydropower.

The main advantages for that the Micro Hydropower represents often, the best solution, are:

- Reliable electricity source: Hydro produces a continuous supply of electrical energy in comparison to other small renewable technologies.
- No reservoir required: Micro hydro is considered to function as a 'run-of-river' system, meaning that the water passing through the generator is directed back into the stream with relatively minimal or no impact on the surrounding ecology.
- Cost effective energy solution: Building a small-scale hydro-power system can cost from \$1,000 to \$18,000 USD/kW, depending on site characteristics, power plant size and location. Maintenance costs are relatively small in comparison to other technologies.[2]

The intense promotion of Micro hydropower plants for renewable energy sources, was also due to the fact that this small-scale energy solutions, are considered environmental friendly, while hydropower facilities with greater power installed have a known negative impact. This is only partially true, since small hydropower brings also environmental effects, which must be considered when authorizing. Of these adverse effects, the most important are:

- impacts during the construction, when are completed the technological roads, water deviations from the future site, disturbance of the sediments in the river bed and/or depositing of building materials in water, noise, landscape, etc.;
- ecological impacts of the deflected water flow and the risk of insufficient flow through the natural river bed;

- effects on fish and other organisms passing through the turbine with the water from the intake.[1]

2. Components of a MHP scheme

At Micro hydropower plants schemes (Figure 1) with large or medium head, the water is diverted by the weir through an opening in the river side (the intake) into a channel (this could be open or closed, under or above the ground, depending upon the site conditions). A settling basin (desander) is built to remove sand and silt from the water. The water is then directed by the channel into a small reservoir/tank called the forebay, from where it is directed on to the turbines through a closed pipe known as the penstock.

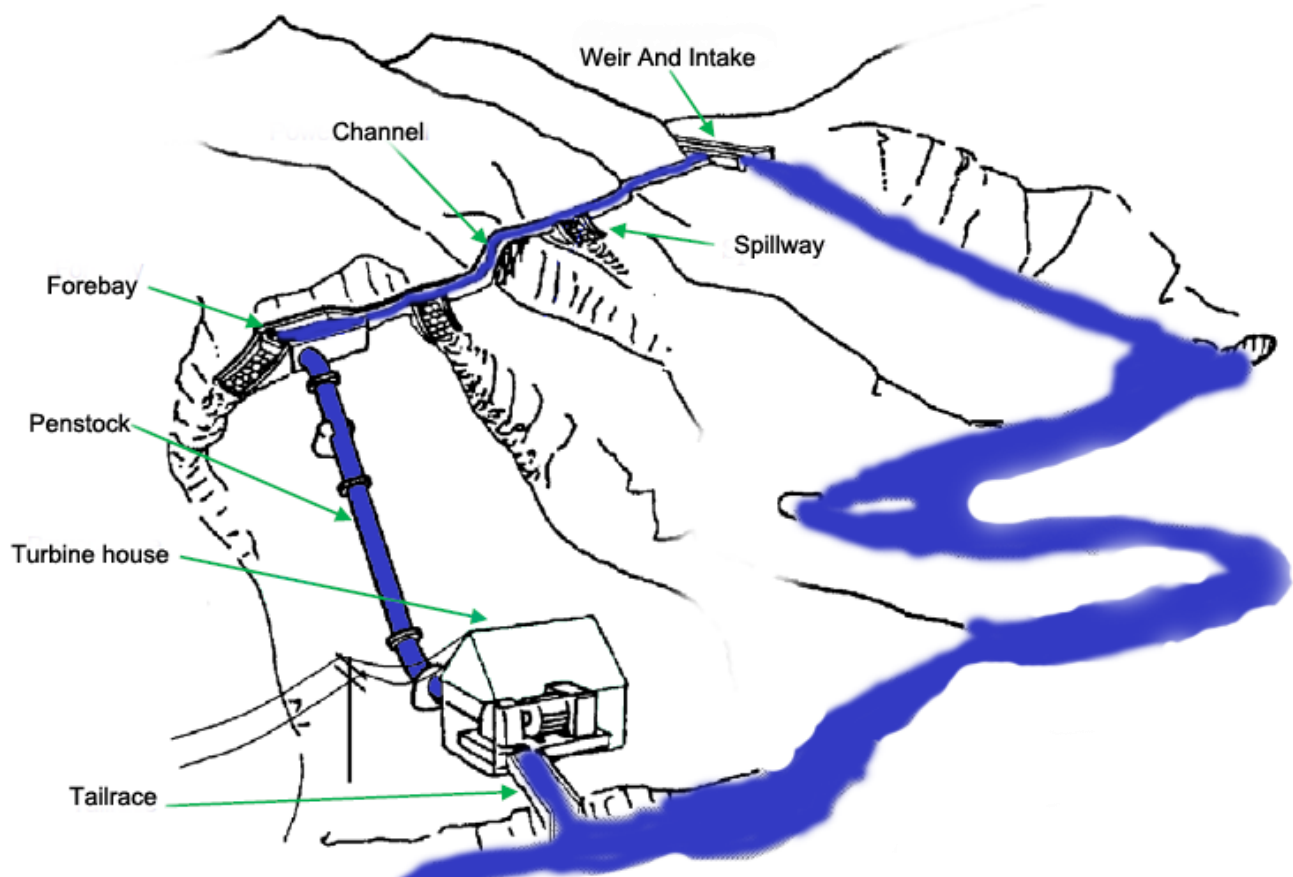


Fig. 1. MHP scheme (Source: A guide to UK mini-hydro Developments, BHA 2005)

The subject of this paper is represented by the MHP with medium and high head, it presents the particularities and the problematic of the hydraulic actuation system, for the hydromechanical equipment, specific to this particular hydro-technical constructions.

Regardless, the solution adopted for the derivation, it is useful to include in the scheme a small lake, capable of storing the captured flow during the periods when the power plant doesn't work, without losing water through the discharge. The location may be in the vicinity of the forebay, associated with a desander, or at the end of the adduction as a forebay tank.

MHP schemes, with low head may be bypass or dam. In bypass schemes the head is created through the construction of a water derivation channel in the floodplain, with low slope and low roughness.

The characteristics of the components of a MHP are listed below:

- Weir: is used to raise the water level and ensure a constant supply to the intake. Sometimes it is possible to avoid building a weir by using natural features of the river. A permanent pool in river could also act as a weir.
- Intake: is designed to divert only a portion of the stream flow or the complete flow. There are few types of intake used to MHP: side intake with and without a weir, Coanda effect intake and the bottom intake.
- Settling basins: are designed to get rid of particles and sediments. The water flow is allowed to slow down so that the sand and silt particles settle on the basin floor. The deposits are periodically flushed.
- Spillway: acts as a flow regulator for the channel. (See Fig. 1). The spillway is often designed with control gates.
- Forebay tank: serves the purpose of providing steady and continuous flow into the turbine through the penstocks. Forebay also acts as the last settling basin, a trashrack need to be installed to prevent large particles to enter the penstock.

The penstock and the turbine house equipment's are not the subject of this work.

3. The problematics of the hydraulic actuation for hydromechanical equipment

Due to the advantages that fluid power systems have, it become the best solution when you have to drive the hydromechanical equipment of a MHP. In order to design hydraulic drive systems, technically and economically efficient, that involves the knowledge of the particularities of MHP.

The hydromechanical equipment that must be operated at a MHP type hydro construction, can be grouped into 3 categories: sluices, gates, weirs and rack cleaners, all must operate in automatic mode and of course with minimum operating costs. Although, in terms of construction the parts of a MHP are unique to each site, in terms of actuation of the hydromechanical equipment, mentioned above, there are no significant difference, see Figure 2.

As described in Chapter 2, for an optimal and complete solution, for a MHP with medium or high pressure, the equipment that have to be operated are:

- At the Weir with accumulation pool and Intake, it have to drive a sluice (vertical lifting) gate, at the bottom of the pool that flushes the sediments on the bottom, (stroke about 2-4 m).
- The spillway, it is recommended to be variable, mobile, so, often the best solutions are the radial gates or flapper spillway operated by two hydraulic cylinders. If at the weir there is a small accumulation pool, the spillway will be designed to protect all the hydrotechnical constructions, against flooding, including the lake. (stroke about 2-4 m).
- At the Settling basins, it is important to adjust the water inlet and to flush the sediments deposited, by controlling a sluice (vertical lifting) at the bottom of the basin. (Stroke about 2-4m).
- The inclined rack, must be cleaned automatically as it retains leaves and branches, thin bags or other lightweight materials that float and have not previously deposited in the settling basins. Therefore is needed a minimum two hydraulic cylinders to drive an automatic rake and at least one for operating a sluice (vertical lifting) gate to flush the collected waste.

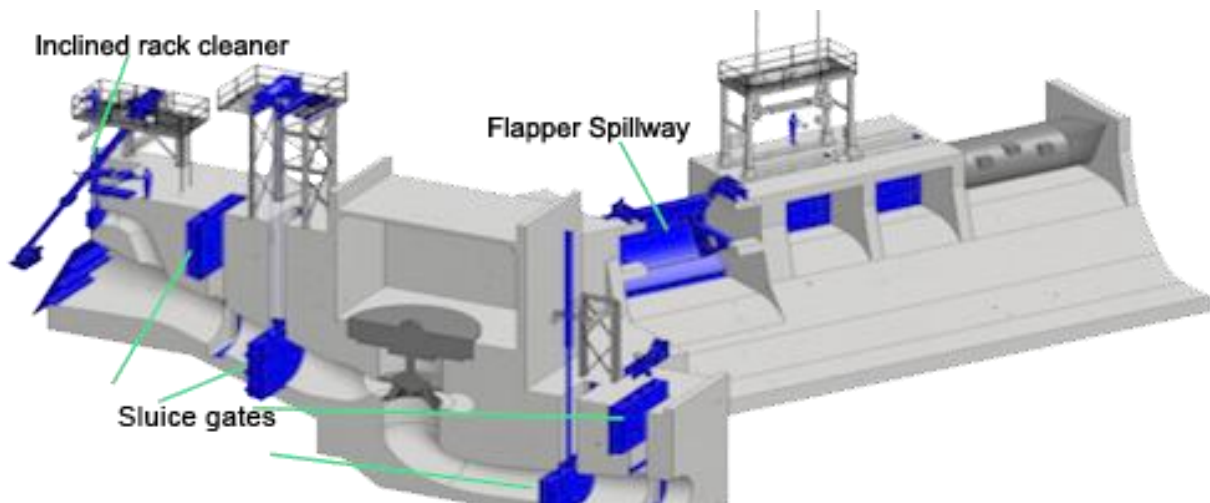


Fig. 2. Hydromechanical equipment for a MHP

Figure 3 presents a simple constructive solution, with two hydraulic cylinders, for automatic cleaner for the inclined racks, sluice gate and flapper spillway.

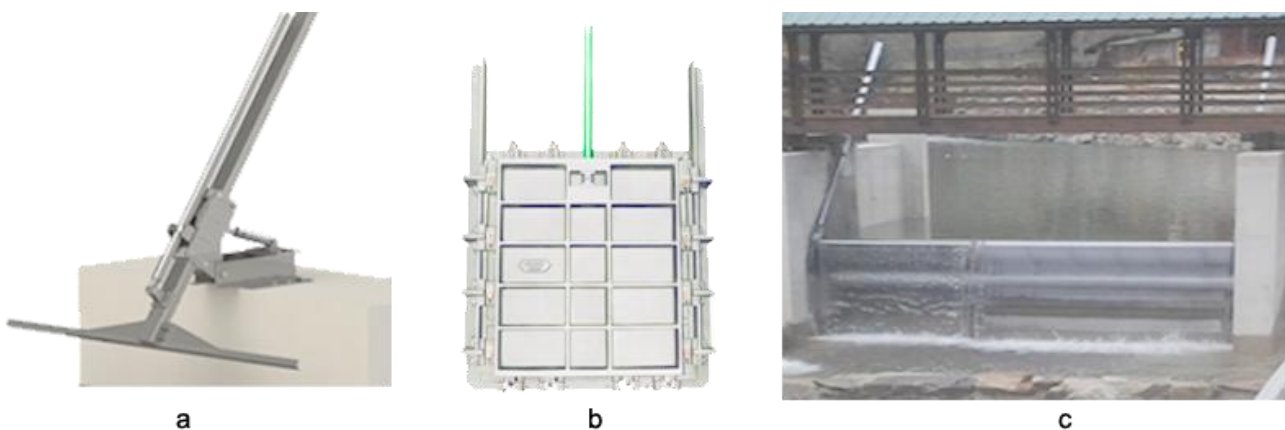


Fig. 3. a. Automatic inclined rack cleaner; b. Sluice gate; c. Flapper spillway

According to those presented above, Figure 4 represents a fluid power system scheme that operates the hydromechanical equipment, specific to MHP.

The problems at these types of systems are related to: energy efficiency and synchronization of the movement when using cylinders in pairs at one single gate (radial or plane).

Although hydraulic systems have wasteful behavior in terms of energy, there are a lot of cases in which they can be kept within reasonable limits [3]. It is well known that in real fluid flow through pipelines and equipment parts, some of the total energy of the fluid is used to overcome viscous friction resistance forces and some is used when the flow velocity changes its direction and / or size. These energy losses can be defined as resistance mechanical work due to the viscous and turbulent resistances. [4]

Energy efficiency in fluid power systems related to MHP's equipment, is strongly influenced by long routes for pipelines, due to relatively large distances between the equipments that must be drive (distances of dozens of meters). It was consisted, practically, by the authors, a significant difference between the pressure loss calculated according to the algorithms from the specialized literature (also software) and the measured values in such a circuit. We consider, this is due to a low interest for very long circuits for fluid power actuation. Moreover, these systems operate in difficult conditions being exposed to all weather and some, even underwater. Because there are

such circumstances, we consider necessary some studies to grow the energy efficiency in this particular types of actuation systems.

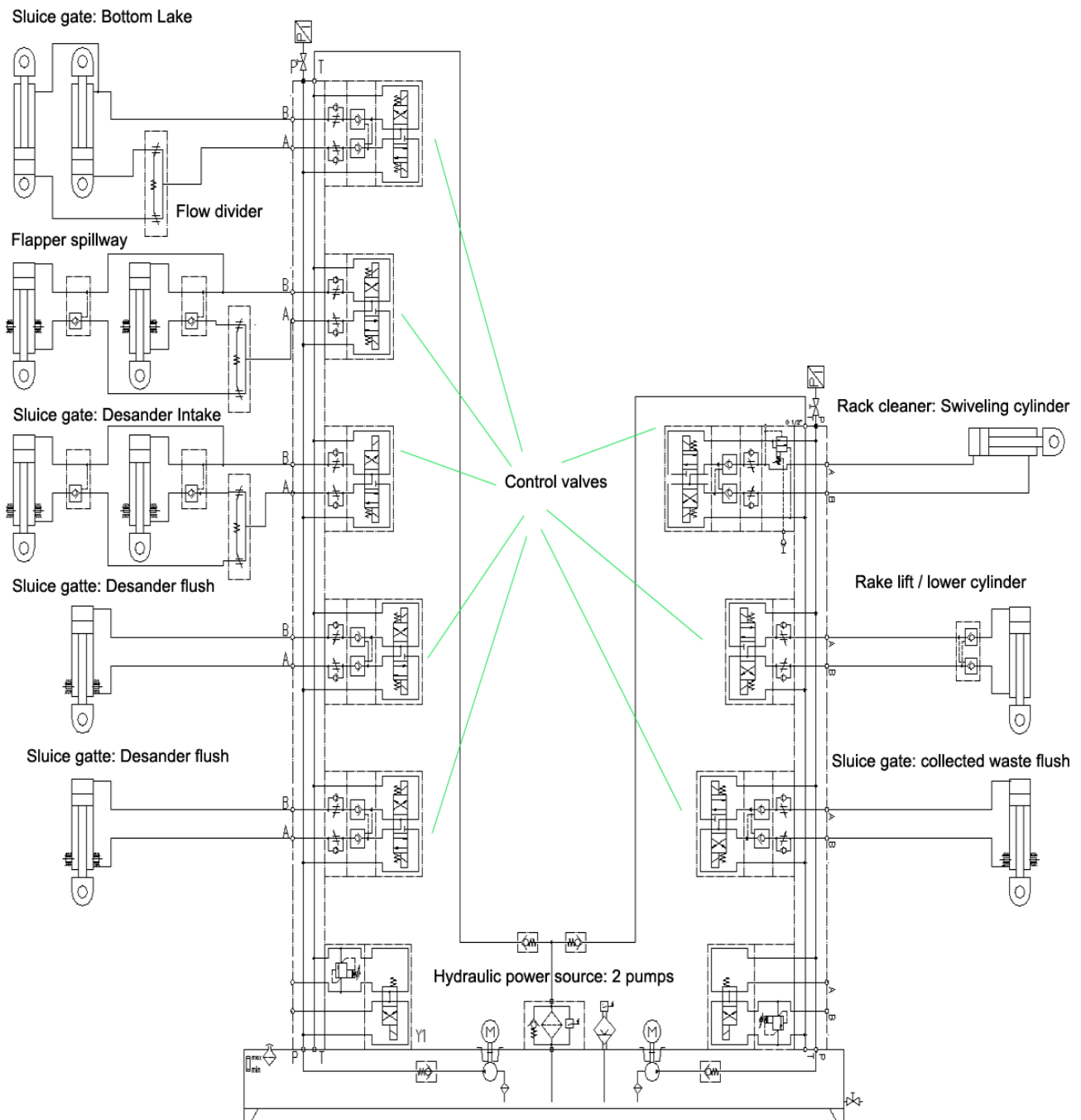


Fig. 4. Fluid power system for MHP hydromechanical equipment

Regarding the synchronization of the movement for the two cylinders which operate one gate, this becomes difficult due to the conditions in which work, the differences in load for the two cylinders can be very large, so there is a risk of blocking the gates. The main causes of the differences in load are the deposits of alluviums and other materials on the raceways or on gates and the corrosion.

If the resistance in the branches is not identical, flow can vary greatly in each path. Adding flow controls makes it possible to change resistance and equalize flow in each branch, but as the gate moves, work resistance changes often require constant flow modifications. To control the flow can opt for servo valves or flow dividers, the first increase costs significantly. A flow divider is a device

that splits flow and compensates for pressure differences. A flow divider can split flow equally, unequally, and into more than two paths. Spool-type flow dividers waste energy, but Motor-type flow dividers do not waste energy and are more versatile. Because flow dividers are not 100% accurate, one of the cylinders may lag [5]. A counterbalance valve must be installed to hold the gate in position at rest, and keeps it from running away.

4. Conclusions

Operating the hydromechanical equipment specific to MHPs, using fluid power systems, in the opinion of authors, remains the most convenient option.

One possible solution for reducing the high pressure losses due to big lengths of the pipes would be the decentralization of the hydraulic power source, i.e. designing compact hydraulic energy sources, mounted, if possible near the operated equipment.

To synchronize the movement, of two hydraulic cylinders, in the most efficient way, it is recommended to use the motor type flow dividers [6], which have the advantage of increasing the pressure between the cylinder and the flow divider, over the maximum set value at the relief valve, without extra energy, so the designed actuation system can operate in very good conditions even when a complicated mechanical blockage occurs. The advantage of the motor-type flow divider over a spool-type flow divider is energy transfer between sections. A spool-type flow divider's inlet pressure is always equal to the highest outlet pressure, and in these situations it is not enough.

Acknowledgments

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