MICRO HYDRO POWER STATION "PROFESSOR DORIN PAVEL" WITH MANY UTILITIES

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One presents the calculus of a micro hydro-electric power station, long ago dreamed by our former famous professor Dorin Pavel, proper to be arranged on the Ciurel Dam at the Mill Lake, on the Dambovita River and very demonstrative for our students practice, to be well specialised on the hydro-electric power engineering field.

We intend to install two hydraulic power machines of good efficiency: one as an axial turbine and other as a turbine-pump reversible machine, to make more familiar the mass of students with the common manoeuvres for one pumping storage power station.

We have to state also that the micro-hydro power plant mainly consists of two type of electric machines, one synchronous and other asynchronous generator; besides, at least one power unit is of reversible type, electric generator-motor, coupled with the related turbine - pump.

Keywords: Hydraulic turbines. Electric synchronous / asynchronous generators / motors. Micro hydro-electric power stations.

1. Introductory considerations. The Special Significance of the Project

It's the real truth, that the plant is still in the advanced design process, at this stage, now. But, how to conduct this designing process and the initial concept - is of high importance, having in mind this double aim: (1) - delivering its amount of kWh as clean energy output, and much more, intelligent locally distributed generation; (2) - the overall management for this energy is versatile conducted in the end, in order to maximize its scientific aim: it will respond at the best within the delicate process for teaching – learning for our students involved in the branch of power engineering education.

By the far, frankly we have to say, this second aim have nothing to do with some loss regarding any real practical aspects.

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2. The General Concept and Final Aim

Training at the best isn't an easy task, everywhere into the Universities - around the world, without a practical, well conceived tech base - even at small installed power, let say - hundreds of kW, as we do point here. Such an intelligent base created with a special architecture in machinery, primary / secondary circuitry and revealing a bounty of phenomena, have to be seen as real opportunity to harden the preparation of our students.

Confining the paper's ideas, it obviously does respond to the main following main aspects, so:

(1) - how large could be the extension of the primary scheme, so that the secondary attached schemes is to color enough the real situations currently encountered into one common power house;

(2) – how to draw maximum from these educational efforts devoted to our students in standard preparation at the power engineering faculty, in order to better fit with their future jobs at the power industry PI; for the advanced student category involved in their master or Ph D program, the problem could be how to short their program;

(3) – the last but not least, stands the aim for distributed generation in order to locally generate/absorb some significant kWh, modeling from standard up to complex operational regimes encountered for one MHPP, e.g. with storage energy facilities.

3. The Hydro-mechanical Part

3.1. The Location and New Design

Because there is no free space on the river bed to place the new power station and also to eliminate the adjacent power losses, we did decide to erect the whole building-power house as a MHPP - let say one *HPP of dam-type*, [3][4]; in other words, we have decided to locate the power house closed to the existing dam's ending part and so to continue the in-feed water pipe of 1.4 m diameter, now prolonged into this newly added power house.

In the *Table 1*, we did calculate for different heads *H*, the speed values *V*, of the water flow *Q*, into the pipe assumed to be of 0.6 m in its cross section diameter *D*; furthermore, following some original calculations for axial hydro power turbines – as it was stated by the first author in the references [5-7] - for maximum rotational speeds ***n***, avoiding the cavitation effect, it was pushed further the MHPP's overall efficiency by maximization the extracted power P. Special careful new design for the turbine's blades, have conducted in this way to far improved rapidity n_s, as it can be clearly seen below.

- for the definite, net head in turbine H_{net}, by applying the well known Bernoulli relation, we have

$$H_{net} = H_{brut} - \sum h_r = H_{brut} - \sum\left(\lambda \frac{L}{D} + \zeta\right)\frac{V^2}{2g}, \qquad (1)$$

- from which, results the speed V and the flow Q of the water through every diameter D of the pipe having the cross section S, so

$$V = \sqrt{\frac{2g\left(H_{brut} - H_{net}\right)}{\sum\left(\lambda \frac{L}{D} + \zeta\right)}} \rightarrow Q = \frac{\pi D^2}{4} V = SV, \qquad (2)$$

- the available power at turbine’s shaft and at the electric generator’s terminals, of efficiencies η_{turb}, η_{gen} is

$$P_{turb}(\text{kW}) = \frac{\gamma Q H_{net}}{102}\eta_{turb} \rightarrow P_{gen}(\text{kW}) = \frac{\gamma Q H_{net}}{102}\eta_{turb}\eta_{gen}, \qquad (3)$$

- the turbine’s rapidity for the admited speeds ratio for which, $U / V \cong 3{,}3 \rightarrow n = 3{,}3 \times 60\ V/\pi D$

$$n_s = \frac{n}{H_{net}}\sqrt{\frac{P_{turb}}{\sqrt{H_{net}}}} = 3{,}65 \frac{n}{H_{net}}\sqrt{\frac{Q}{\sqrt{H_{net}}}}, \qquad (4)$$

with which occasion we do realise the high value of the turbine’s rapidity n_s, and also
the fact of being independent as regard the available head H.

According with the figure 1 the rotational speed component obtained by the
directory blades system, is

$$C_{u1} = \frac{gH_{net}}{U_j\left(R_j\right)}, \qquad (5)$$

with the rotational speed for the tronson of the blade

$$U_j = \frac{\pi D_j n}{60}, \qquad (6)$$

and the meridian component for the absolute fluid speed will be

$$C_{m1} = \frac{4Q/\pi}{D_{cond}^2 - d_{butuc}^2}, \qquad (7)$$

where C denotes the number of channels for the whole water flow considered here into the calculation.

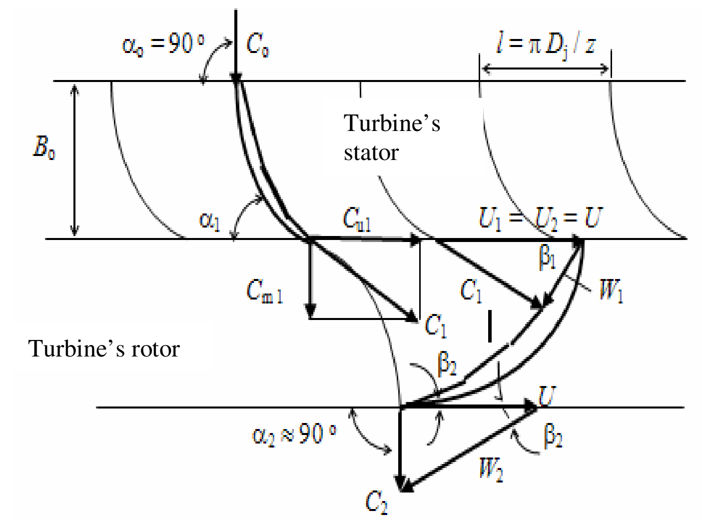

Fig. 1. Stator and rotor blades, the current lines in the absolute movement and the speed triangles at the inlet and the outlet of the rotor.

In the figure 1 it is shown the profiles of the stator and rotor blades with their speed triangles. In the figure 2 it is shown the rotor prototype of an axial turbine which was tested onto the glass channel model from the Hydropower laborator *Professor Dorin Pavel*, which offers at the small speeds of the stream liquid, one very good, uncommon performance of the maximum power coefficient $C_p = 0{,}56$ – as i tis already presented into the figure 3.

Table 1

H **(m)**	***V*** **(m/s)**	***Q*** **(m^3/s)**	***P*** **(kW)**	***n*** **(r.p.m.)**	***n*** **s**
2	5,49	1,55	16,7	577	1591
4	7,77	2,20	47,3	817	1591
6	9,52	2,69	86,9	1000	1591
8	**10,99**	**3,11**	**133,8**	**1155**	**1591**
10	12,29	3,47	186,9	1291	1591
12	13,46	3,80	245,7	1414	1591

The generous diameter at the cross-dam pipe D = 1,4 m is suitable for the triple derivation $3d$ = 3× 0,4 m diameter for each power turbine unit (e.g. of special rapid turbine type, vertical position – until other pertinent researching efforts are done). In fact, the MHPP in question is thought mainly as a real training lab and related testing place for the best scientific solutions in the field.

These new solutions are regarding as the best electro-hydro-mechanic energy conversion techniques, with machineries of advanced, may be world wide of complete new designed type, as we can show below, for power turbines / pumps, following these above relations (1-7), as mathematical support.

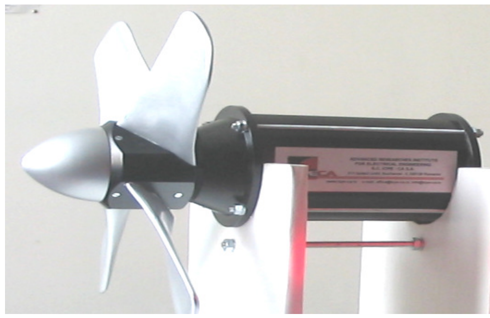

Fig. 2. The aspect of the axial hydraulic turbine rotor

In the case of reversible turbine-pump, we did adopt for the blades' construction, some original simetric profiles, having the maximum thickness at the middle of the blade and using the well known Coanda's effect against the take off phenomena for the fluid, as leaving the profile' surface.

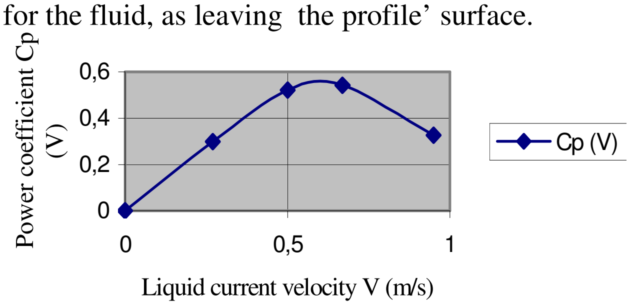

Fig. 3. Power coefficient variation versus the liquid current velocity, for the turbine rotor type shown in the figure 1

Fig. 4. The photo taken on the actual Ciurel-dam near-by the Polytechnic University of Bucharest, ready to admit on the left side, the closed plant MHPP in question, rated 3•100 kW, as installed power.

4. The Electric Part

On the *primary side*, the management for the complex power machinery part is quite the same as in reality; even the output ranges around 100 kW, the care and the operational complex regimes is the same as for the HPP with MW output; besides, changing the regimes from generator / motor – turbine / pump, synchronous / asynchronous type at fixed or variable frequency; So, we do cover all significant and so maximized possibilities to teach at the best our students not only here but standing as an example, everywhere in the world of tech universities, where really does exist the desire for *one quality teaching process*.

The general power electric scheme for the main types of generators is presented into the next figure 5.

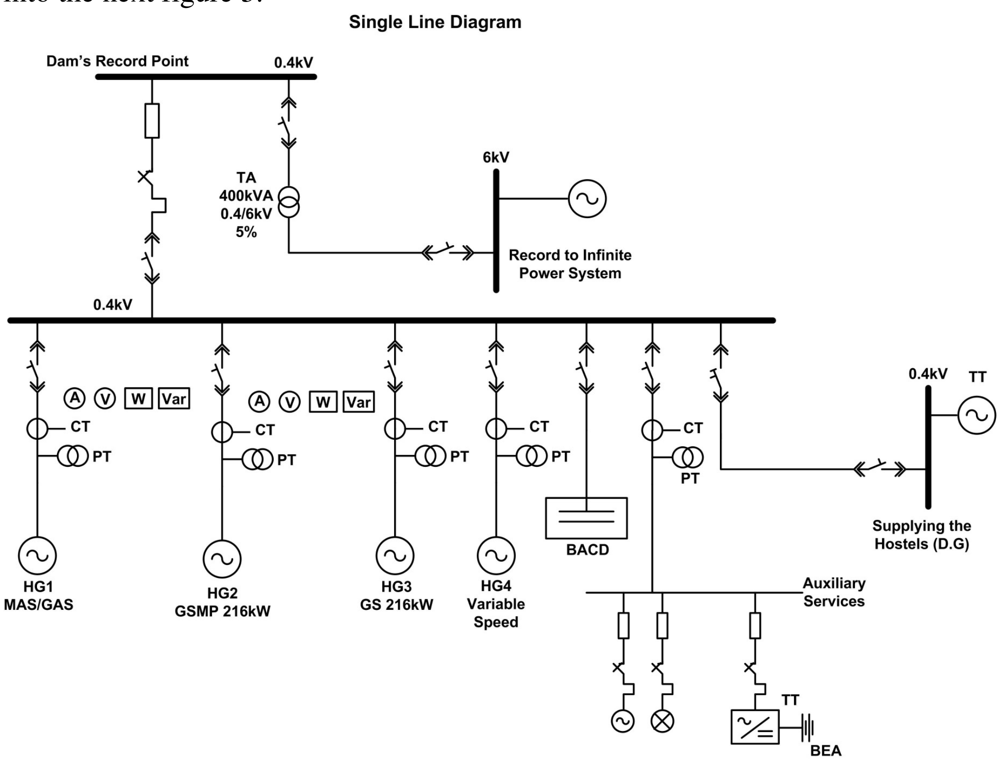

Fig. 5.The general electric lay out diagram for distributed generation proposed scheme for the present MHPP

a. In the same time we think to be in line with the *European Program of Distributed Generation in* Associated *States – DIGENAS*, [8]. The following main considerations are below listed. So,

b. Considerations on the power electric side. The final general requirements, as we do hope, are to be gathered the main investment into: the electro-hydraulic machinery, the envelope building for the machines' room, is also the class room prevented at the power house (or better at the first floor), also some demo facilities for wind - combined with solar - power generation, accommodated onto the roof, as superior level, if finally will be approved.

c. Commercial aspect. The main power units, rated 2¤100 kW, connected to the local grid of 0.4 kV, 50 Hz, via the compact distribution bloc cubicles, will cover firstly the dam's ancillary consumers, then excedentary power, injected into the medium voltage m.v power grid 6/20/110 kV unit of PMG type will be coupled to the grid, producing its kW and also its implicitly kVAr, as the reactive task is usually of local interest and necessary.

d. Educational aspects. One quality teaching process, tech. University level could be sustained for common students, masters and graduated students preparing their Ph D works.

5. Some Pertinent Conclusions

We spoke about one small hydro-power plant MHPP prevented from their initial design with its maximum versatile features: to generate electric energy and to educate at the best the young generation of students. So, the final aim is double - firstly, to inject some modest power, even demonstrative – in/out from the network; secondly, in parallel to reduce the probable rate for next mistakes, however done by our future power engineers working into the real scaled, bulky power systems. Besides, into (or over !) the machines' room we hope to manage one classroom for students; over this, onto the roof, we do hope to accommodate one demo-park for *wind* and *solar* reliable energy converters.

We could add the third aim, which stands for quality scientific research devoted to our students etc., and also for the power industry PI itself, in order to test the new regulators prevented with adaptive PSS, digital protective relays, working into specific dynamic regimes for different external reactance and power units' mechanical inertia constant etc.

One turbo unit is asynchronous type, the other one could be of synchronous type with permanent magnets as generator/motor – PMG, very reliable and devoted to kW+kVAr production; however, the third one have to be one pure synchronous classic generator/motor, but up-to-date prevented with different system excitation and automatic voltage and speed regulators, at different complexity and devoted to experiments, researching studies.

All the scientific worthy efforts done at the level of this small but intelligent designed MHPP are to be further disseminated into one responsible bulky power systems, ready to proceed it, just in order to obtain one desired revitalized at higher reliability for the main operational regimes, both generation or motoring – the last one for storing energy purposes.

The fully completed MHPP will include practical schemes and operational regimes describing both the turbines of new design and electric machines at work, regarding the new design concepts – so, double aim responding: electric energy locally generated/absorbed in parallel with one high quality teaching – learning process, mainly devoted to the students involved into the power engineering field.

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