Project Proposal for the Picoidraulica Laboratory

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Project Proposal for the Picoidraulica Laboratory

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Abstract. This project-oriented work, is a pre-feasibility study of a pico-hydraulics plant, which has to be installed on an appropriate structure in UBT - University for Business and Technology at Pristina, the capital of Kosovo. It begins with the structural analysis of the designed laboratory, moving on through to the technical-economic study of the individual components, concluding with the definition of its effectiveness, based on the actual data of the plant. The purpose of the plant comes from the idea of fully exploiting the energy available in a public building, with special regard to what is daily discarded without being exploited. It will be analyzed the feasibility and the convenience of the recovery of the grey water potential energy from buildings of considerable height (100 – 200 meters) through a hydraulic turbine.

Keywords: Energy Efficiency, Pico Hydraulics, Green Energy, Architecture and Design, Reduction of Carbon Dioxide Emissions, Water Consumption Management.

Introduction

Architectural and engineering studies are increasingly involved in the design of so-called sustainable skyscrapers: structures that combine the high density of urban centers with the need to contain the energy needed and the integration of renewable energies. "The densest cities, with less suburban development, fewer roads and more public rail transport, are the only solution to support the impact of the rapid turbulence of the population," says Ken Shuttleworth, an English engineer who, along with Norman Foster, realized the Gherkin (the seventh highest building in London), the new City Hall, the Millennium Bridge and still directs London towards the so-called “vertical design”. Building vertically means to reduce soil consumption and this in itself is an element of sustainability. But the height is not enough to declare the low environmental impact of a structure. Skyscrapers, due to their size, are very complex structures, and to ensure high energy performance, become necessary a close collaboration between architecture and engineering.

With the adoption of the European Directive (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 which amends Directive 2010/31/EU on energy performance in buildings and Directive 2012/27/EU on energy efficiency, the new EPBD - Energy Performance Building Directive, it was introduced the concept of "Nearly Zero Energy" for new (or even old) public or private buildings. With nZEB - Nearly Zero Energy Buildings – that means highly energy-efficient buildings characterized by very low or almost zero power requirements that have to be significantly covered by energy from renewable sources. Particularly interesting is EPBD art. 9, which states that all newly constructed buildings from December 31 in 2020 are almost zero, while for public buildings the deadline is anticipated on the 31 of December in 2018.
P60 – nZEB for the UBT

The central subject of this study will be the construction of the laboratory of a P 60 nZEB, a 60 floors structure with renewable energy systems, low impact technologies and a complete energy efficiency. This structure will be located in Pristina, Kosovo, particularly within an area of the Campus UBT, University of Business and Technology: the aim of the final project is to test the possible energy independence of this area through the use of renewable sources and technologies with almost zero impact. The technology introduced is Pico Hydraulics system, a technology for the exploitation of hydroelectric potential of grey water to produce electricity. This energy transformation system, introduced in the P60 buildings, aims at achieving three fundamental objectives: the first is the energy recovery of the water supply of the building, the second is the reduction of CO2 emissions, and the third is the reduction of primary energy consumption from the network, planning to build in the same university area also a photovoltaic PV creating a smart grid with the building.

This study, reported in the following chapters, deals with the preliminary laboratory phase: it consists in describing the design choices and in the analysis of the components of the simulation structure of the plant with final design and economic feasibility study.

Fig. 1. The Gherkin, London

Pico Hydraulic Plant

Purpose of the residential hydroelectric plant

The purpose of the plant comes from the idea of fully exploiting the energy available in a public building, with special regard to what is daily discarded without being exploited. It will be analyzed the feasibility and the convenience of the recovery of the grey water potential energy from buildings of considerable height through a hydraulic turbine.

Storage system analysis
In order to overcome any problems linked to the structural resistance of the residential floor and at the same time maximize the electricity production, an innovative configuration of the hydroelectric plant has been devised. This provides two types of storage tanks: secondary tanks and a primary collector.

![Fig. 2. New type of storage tanks](image)

The first are placed on each floor of the building, with the exception of the first ones that are too low and have a capacity of 450 liters, the other is a single vertical cylindrical tank having a diameter comparable to that of the exhaust pipe of the gray water, closed below this by a valve. The latter, controlled by the electronic control unit, regulates the opening and closing of the connection between the primary tank and the Pelton turbine distributor. Other valves are required on each floor, placed between a secondary tank and a primary, as well as a filter that is laid out in each floor to remove the impurities from the gray water that will accumulate in the secondary reservoir. This type of plant has the obvious advantage, beyond the feasibility, of maximizing the flow of turbine liquid: it will in fact contribute to the gray water of each floor of the building (excluding the first ones for a reason related to low potential energy) and not only those placed above a large reservoir, as previously thought.

The laboratory

Starting from a preliminary description of the studied structure, we examine in detail each component necessary for the life simulation cycle of the P60 structure. With subsequent energy analyzes, the feasibility criteria of the laboratory are reported and the economic weight of the possible implementation is determined.

Structure

Elevating small laboratories at different rates, how many are the plans of the building in question, it is evident that it would be complicated and difficult, both in terms of construction itself and economically. As a result, it is decided to create a single, smaller size structure that can estimate the reliability of the total plant. It is a simple and practical configuration that can highlight problems arising from a continuous flow of the turbine water, and thus simulate the life cycle of the building over a given period of time. Consider the following closed simulation system (see Figure 3):
Components and devices:
- Tanks A:
  - Material: PVC (type NANA 3000S);
  - Capacity: 3000 l;
  - Diameter: 1650 mm;
  - High: 1720 mm.
- Tanks B:
  - Material: PVC (type CLYVER 3000S);
  - Capacity: 3040 l;
  - Diameter: 1450 mm;
  - High: 2520 mm.
- Pipe/conducts C:
  - Material: Polyethylene;
  - Section diameter: 80 mm.
- Turbine-generator unit and technical compartment (D);
- Submersible Electropump in sommersione (inside B) (E);
- Lifting work chosen.

The main aim pursued for the design of this laboratory is to optimize energy, in order to minimize installation and management costs. The selection of the best turbine for each particular hydro site generally depends on the features of the site itself: the dominant factors are the head available and the power required. This selection also depends on the speed at which the generator or other devices driven by the turbine.

In this case, the features considered are:

<table>
<thead>
<tr>
<th>Structural characteristic of the lab</th>
<th>Characteristic of the device to fed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available head (H=25 , m)</td>
<td>Power required by the pump</td>
</tr>
</tbody>
</table>
Pump

With the ideal goal of creating an auto-efficient system, the first energy analysis concerns the pump. The best configuration that minimizes the Hp prevalence of the machinery, is characterized by the presence of reservoir tank downstream of the turbine. Within the same reservoir, it was assumed to place an electric pump to further reduce leakage. This component brings the fluid into a quiet state, thereby eliminating the losses that would have occurred at the suction with the fluid at high speeds. It is more advantageous not to take into account the high concentration losses due to the strong impact on the outlet and at the entrance of the two machines, considering the high kinetic high of free falling water.

Fig. 4. Reservoir tank downstream of the turbine

Here are the calculations made and the values of the parameters considered for estimating the hydraulic loads in inlet and outlet of the pump:

- **Hydraulic load outlet:**
  \[
  H_{2_{\text{outlet}}} = \frac{P_{\text{atm}}}{\rho g} + \frac{Q^2}{2g} + z_2 + \Delta H_2 \quad (1)
  \]

- **Hydraulic load inlet:**
  \[
  H_{1_{\text{inlet}}} = \frac{P_{\text{atm}}}{\rho g} + \frac{Q^2}{2g} + z_1 + \Delta H_1 \quad (2)
  \]

Table 2. Factors for calculating the hydraulic loads in suction and delivery

<table>
<thead>
<tr>
<th>Inlet/Suction</th>
<th>Outlet/Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>( z_1 = 0 )</td>
<td>( z_2 = 25 ) m</td>
</tr>
<tr>
<td>( p_1 = P_{\text{atm}} = 10^5 ) Pa</td>
<td>( p_2 = P_{\text{atm}} = 10^5 ) Pa</td>
</tr>
<tr>
<td>( Q = 5 \text{ l/s} )</td>
<td>( Q = 5 \text{ l/s} )</td>
</tr>
<tr>
<td>( D = 8 \text{ cm} )</td>
<td>( D = 8 \text{ cm} )</td>
</tr>
<tr>
<td>( \Delta H_1 = \Delta H_1_{\text{distributed}} + \Delta H_1_{\text{concentrated}} )</td>
<td>( \Delta H_2 = \Delta H_2_{\text{distributed}} + \Delta H_2_{\text{concentrated}} )</td>
</tr>
</tbody>
</table>

It follows that the value of the prevalence, that is, the maximum lifting difference expressed in meters is:

\[
H_y = H_2 - H_1 = 25 \text{ m} \quad (3)
\]

Known this parameter, the characteristics of the submersible pump that best meet the needs of the laboratory have been evaluated. Submersible electropump SERIES S4 della DAB PUMPS.

Table 3. Constructive characteristics of the electropump
Table 4. Constructive characteristic of the motor

<table>
<thead>
<tr>
<th>Technical data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
</tr>
<tr>
<td>Minimum fluid temperature:</td>
</tr>
<tr>
<td>Maximum fluid temperature:</td>
</tr>
<tr>
<td>Rated flow rate:</td>
</tr>
<tr>
<td>Rated head:</td>
</tr>
<tr>
<td>Efficiency:</td>
</tr>
</tbody>
</table>

Table 4. Constructive characteristic of the motor

<table>
<thead>
<tr>
<th>Technical data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power:</td>
</tr>
<tr>
<td>Rated voltage:</td>
</tr>
<tr>
<td>Rated current:</td>
</tr>
<tr>
<td>Frequency:</td>
</tr>
<tr>
<td>Power factor:</td>
</tr>
<tr>
<td>Efficiency:</td>
</tr>
<tr>
<td>Number of poles:</td>
</tr>
<tr>
<td>Rated velocity:</td>
</tr>
</tbody>
</table>

Characteristics of the electric devices:
- Electronic control panel for motor protection, control and command with direct starting;
- Electric accessory for command and control: Active Driver Plus.

Turbine-generator unit

On the one hand, with the aim of balancing the structural requirements of the laboratory (exploitable head) and, on the other hand, with the external imposition of the devices powered by the turbine (in particular the power of the pump), the choice of the machine group fell on the following set:
- Turbine Group - ECOWATT Generator (IREM Module TPD24 / www.irem.it) Composed of:

Table 5. Micro Peltone turbine: main characteristics

<table>
<thead>
<tr>
<th>Technical data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type:</td>
</tr>
<tr>
<td>Usefu head:</td>
</tr>
<tr>
<td>Flow rate used:</td>
</tr>
<tr>
<td>Generated electric power:</td>
</tr>
<tr>
<td>Rated voltage:</td>
</tr>
<tr>
<td>Type blades:</td>
</tr>
<tr>
<td>Material:</td>
</tr>
</tbody>
</table>

Table 6. Generator (type.G503/B)
The characteristics of other devices are here omitted; there are:

- Turbine-generator housing;
- Power supply unit;
- Electronic regulator with heat dissipation in the air.

### Lifting work

In order to have an available head exploitable by the hydraulic turbine of the value of about 25 meters, two alternatives for lifting the tank have been evaluated. Use existing buildings or hills on the university campus. Construction of a permanent tower with support platform at the top. The first option would be the most risky from the point of view of security: the positioning of the tank system and piping on the top of a pre-existing structure could go undo its normal operation. Incidental events such as water leakage from piping with consequent flooding or mechanical stress given by the weighing of the plant would cause enormous damage, especially since the facilities inside the campus are mainly equipped with very delicate electronic machinery and equipment subject to easy deterioration. On the other hand, the simple placement of the tank would only require lifting costs, by crane machinery in the order of a few hundred euros. The second option presents the evaluation of two technologies compared: - Steel tower on reinforced concrete foundation - Tower and foundation in reinforced concrete with burglars. As opposed to the first, this alternative for both technologies has high construction costs: the cost is around € 25,000, considering both the foundations and the structure. This is a preliminary estimate as, for the construction of that type of works, a soil study is required, with a geological and geotechnical report that may highlight weight incidence problems: the possible design of piles, due to the presence of clayey or friable terrain obviously represents an additional burden.

### 5. Work cycle

The previous analysis of the components of the laboratory was not based on the concept of continuous flow: the type of work cycle that is considered is the intermittent cycle based on the charge-discharge of the reservoir upstream of the turbine:
The drainage takes place with a tank discharge time equal to:

\[ t_{svuotamento} = \frac{3000 \text{l/h}}{3 \text{l/s}} = 16.7 \text{ min} \] (4)

The charging takes place with a tank filling time equal to:

\[ t_{riempimento} = \frac{3000 \text{l/h}}{5 \text{l/s}} = 10 \text{ min} \] (5)

This is a particularly advantageous solution both from an energy point of view and from the point of view of the life of the turbine itself. In this way, it is not necessary to balance the flow rates and powers of the plant machinery, but mostly, the stresses to which the turbine is subjected are not dynamic due to a frequent load, but are cyclic-static, resulting in a lower risk of damage to all shaft or other parts of the machine, ensuring a longer working life.

**Cost analysis**

The following economic assessment analyzes the cost of realizing and installing each alternative considered.

**Table 7. Pump and annexes devices**

<table>
<thead>
<tr>
<th>Component</th>
<th>Price €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submersible electric pump SERIES S4</td>
<td>€ 821.00</td>
</tr>
<tr>
<td>Electric panel for protection/command</td>
<td>€ 258.00</td>
</tr>
<tr>
<td>Active Driver Plus</td>
<td>€ 60.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>€ 1,139.00</strong></td>
</tr>
</tbody>
</table>

**Table 8. Turbina-Generator unit and annexes devices. Certification of IREM: based on standard ISO 9001, ISO 14001, BS OHSAS 1800**

<table>
<thead>
<tr>
<th>Component</th>
<th>Price €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbina-generator unit Ecowatt</td>
<td>€ 3,550.00</td>
</tr>
<tr>
<td>Electronic regulator with heat dissipation in the air</td>
<td>€ 1,380.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>€ 4,930.00</strong></td>
</tr>
</tbody>
</table>

**Table 9. Polyethylene reservoir tank**

<table>
<thead>
<tr>
<th>Component</th>
<th>Price €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank (A)</td>
<td>€ 950.00</td>
</tr>
<tr>
<td>Tank (B)</td>
<td>€ 1,100.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>€ 2,050.00</strong></td>
</tr>
</tbody>
</table>

**Table 10. Pipe and conducts**

<table>
<thead>
<tr>
<th>Component</th>
<th>Price €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe in PVC of D= 80 mm</td>
<td>5.78 €/m</td>
</tr>
<tr>
<td>Connection curve 87° in PVC of D=80 mm</td>
<td>2.67 €/pezzo</td>
</tr>
<tr>
<td>Therefore, considering a total length of pipes of about 52 m, and 4 connection curves:</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>€ 30,067</td>
</tr>
</tbody>
</table>

**Table 11. Lifting work**
The results are a general cost of the simulation system of € 8,496.00, to which the additional weight of the option chosen for the lifting work must be added.

Conclusions

This work describes the design of the picoidraulics laboratory to be realized at UBT, in an area located in the university campus. Summing up the considerations made above, the project provides:

- The construction of a picoidrolectric plant consisting of the basic mechanical components described above and related electrical control devices;
- The possible creation of a supporting structure for the tank at high altitude.

With regard to energy sustainability, the future wastewater recovery plant will certainly be more interesting if integrated with other renewable technologies. Following the energy analysis of the planned plant, the "PV-pico hydroelectric" connection is convenient, providing the energy needed to cover the energy delta between the output power available from the hydraulic turbine and the greater input power consumed by the pump to close the cycle plumber. This project has low implementation and maintenance costs, due to the particular type of "intermittent " lifecycle assumed, so that the lifetime is significant, considering the low risk of damage of the machinery.

In conclusion, the plant described above can boast a high level of reliability and safety combined with limited implementation costs.

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Reformed Methanol Fuel Cells: Proposed Plant for Vehicular Applications

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Abstract. Among the various possible applications for a reformed methanol fuel cell, in addition to the portable generation in remote areas and military use, the use in the automotive field is interesting and promising. RMFC is used as "range extender" in battery-powered electric vehicles. This would increase the driving autonomy of the electric vehicle making it no longer strictly dependent on the capacities of today's batteries, eliminating the problems associated with them, such as the battery pack weight and overall dimensions. Besides, they need for recharge to short-term and are characterized by very high hazard in the event of a car accident (today's lithium ion batteries - if heavily damaged - tend to generate fires difficult to extinguish). In this paper the possibility to design and realize an onboard plant has been studied and evaluated. The various characteristics of the cells are analyzed and a first preliminary system is studied in all its components. The next steps, in addition to optimizing the plant, will be to evaluate the economic feasibility and the various systems of methanol supply.

Keywords: RMFC, onboard power plant, range extender, thermal feasibility, energy efficiency, reduction of carbon dioxide emissions.

Introduction

The H2 fuel cells was initially presented in 1843 by sir William Grove, published in the December 1838 edition of The London and Edinburgh Philosophical Magazine and Journal of Science. This technology has become immediately of interest for the possibility of producing energy in a continuous and high efficiency way. Moreover, the H2 can be produced through different renewable processes. The most common hydrogen fuel cells are of Polymer Electrolyte Membrane (PEM) type. In these devices, the hydrogen and oxygen react by generating water and electricity, which can be used for specific functions. A PEM fuel cell consists of two electrodes, the negative anode and the positive cathode, separated by a membrane (PEM) that only allows the transport of positive ions. Hydrogen is supplied to the anode where it is distributed through a Gas Diffusion Layer (GDL). The anode is composed of metals that act as a catalyst (usually platinum) which facilitate the separation of molecular hydrogen into ions. The positive hydrogen ions migrate through the membrane until they reach the cathode, where they react with oxygen, supplied or in the form of pure O2 molecular oxygen or air. The reaction is catalyzed by the cathode and produces water (see figure). The overall operation reaction is:

\[ \text{H}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{H}_2\text{O} \quad (1) \]