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RESEARCH ARTICLE

ELECTRICAL ENERGY ASSESSMENT FROM KINETIC ENERGY OF DOMESTIC TAPS AND IRRIGATION WATER NETWORKS

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ABSTRACT

With this study, we intend to contribute to the promotion of micro hydroelectric power plants for individual, family and community use. We pay a particular attention to sustainable and affordable solutions that could be used in isolated sites with relative less investment. For this purpose, we demonstrate the possibility of generating electricity from hydraulic energy of water flow in domestic taps and agriculture irrigation valves. Through examples of daily water needs of an average household and an irrigated farm, we estimate the electrical energy that could be generated by installing a suitable small turbine. In the case of irrigation water flow, the estimated quantity of electrical energy is relatively significant and could meet human basic needs such as powering and recharging daily household devices on isolated sites. The electricity is produced when the water flows. It is then necessary to store it in adapted batteries. We also underline the fact that the presented solutions are sustainable because the turbines recover an energy that was supposed to be lost.

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INTRODUCTION

To address the causes of climate change and difficulties in accessing electrical energy, a significant number of initiatives are contributing to the development of renewable energies. Hydroelectric power plants represent one of the largest sources of renewable energy (IEA, 2023), (K. Decker 2013), (C. Louis *et al.,* 1991). In a hydroelectric power plant, the height of the water fall allows the transformation of the potential energy of the liquid into kinetic energy. The speed of the water activates a turbine and transforms hydraulic energy into mechanical energy. The turbine in turn drives a generator which transforms mechanical energy into electricity. In the 19th century, the water power was largely exploited to drive engines and to produce electricity on a small scale or for individual use (K. Decker 2013), (C. Louis *et al,* 1991). Indeed, compact units consisting of a small water turbine directly coupled to a dynamo were commercially available. These devices made it possible to produce electricity from falling water. Domestic models were mounted on the drinking water taps in order to generate electricity used for lighting and powering radios. Domestic models met with commercial success thanks to the widespread availability of water supply in urban areas. However, the operation of these small plants required a relative large quantity of water which was drawn from public water network and this constituted its main disadvantage (K. Decker 2013). Thereafter, innovation mainly focused on large hydroelectric capacity power plants (O. Paish 2002), (A. Brown *et al*, 2011) in order to produce electricity on a large scale. Nowadays, in many developing countries, accessing to water politics lead to large coverage of domestic connection with water in urban and peri-urban areas while electrical connection remains limed. Solar panels are actually the solution to get lights and powers for daily devices in peri-urban zones.We believe that the possibility of storing energy in affordable batteries makes meaningful to reconsider development and promotion of systems for collecting energy from daily water flow in a household and irrigation network. The objective of this study is to contribute to the promotion of micro hydroelectric power plants for individual, family and community use. The study focuses particularly on the valorizationof the kinetic energy of domestic and irrigationwater distribution networks. Indeed, at the point of delivery (tap or valve), water still has significant kinetic energy (T. Bühler2007). Not all this kinetic energy is necessary for the final use and therefore, the most important part is lost. Recovering this energy will certainly improve access to electrical energy with friendly impact on the environment.

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METHODS

Equations: In a water flow, the pressure P and the flow rate Q are the most important data for calculating the hydraulic power as shown in formula (1).

$$P_h = P.Q \quad (1)$$

Where:

P_h: hydraulic power in W
P : pressure of the water in Pa
Q : water flow rate in m^3/s

P_h is the input power of the turbine. The output electrical power P_e produced by the generator of the turbine takes into account the total yield η_{Tot} of the equipment according to formula (2):

$$\eta_{Tot} = \eta_t \cdot \eta_g \cdot \eta_e$$
$$P_e = \eta_{Tot} P_h \qquad \text{……………………(2)}$$

P_e : output electrical power
η_{Tot} : total yield of the equipment
η_t : yield of the turbine
η_g : yield of the generator
η_e : electronic yield of the equipment

Finally, if t is the duration of the water flow, we obtain the electrical energy E by using formula (3)

$$E = tP_e \qquad \text{………………………(3)}$$

Were:
E: electrical energy in Wh
t: flow duration in hour
P_e : electrical power in W

Electricity from domestic tap water flow: In most websites of national water office, the water pressure in urban pipes generally varies between 2 and 10 bars. An average operating pressure of 3 bars is often considered at taps in a household. Lower pressures are detrimental to water quality. In fact, if there is a leak, low pressures expose the pipes to contamination by infiltration with surrounding water. The flow rate at the tap depends on the final use. For examples, in a tap for general use such as kitchen, handwash, the flow rate is around 12 litres/minute. For shower, bathtub and garden watering, the flow rate could be up to 30 litres/minute. Notice that several taps often work at the same time which leads to a maximum flow rate at the water meter. In this study, we consider the average working pressure P of3 bars, and a flow rate Q of 30 litres/minute. Based on data sheets review of existing turbines and results of preview works (T. Bühler 2007), we can notice that the total yield of a turbine depends on its technology and varies between 0.7 and 0.9. A mean value of 0.8 is considered as global yield η_{Tot} in this study.Considering the latest estimated average household of 5 persons in Burkina Faso (RPGH 2019), we can estimate the consumption of water at 250m^3/year, which is equivalent to a volume V of 0.685m^3/day. If we divide the daily water volume by the flow rate *Q*, we obtain the duration *t* of water flow per day:$t = \frac{V}{Q} = 0.38\, hour$.

Electricity from irrigation water flow: We consider a garden project in the centre of Burkina Faso. The farm has a surface of one hectare. The water is pumped daily from a borehole and stored in large tankslaid on the floor. A manometer is installed at the entry of the borehole, just before the water get into the tanks. When the pump is fully running, the manometer indicates an average pressure of 3.4 bars. The flow rate is measured using a graduated bucket and a stopwatch. The estimated flow rate is Q =5.05m^3/h. A volume of 30 m^3 is daily pumped from the well for watering.

RESULTS

Domestic tap water flow: By using formula (1), the hydraulic power P_h of the water supply is estimated: $P_h = P.Q = 150\, W$.

Formula (2) is used to calculate the electrical power generated by the turbine from the hydraulic power.

$$P_e = \eta_{Tot} P_h = 150 \text{ x } 0.8 = 120 \text{ W}$$

Then, the electrical energy *E* that could be produced per day is calculated:

$$E = \frac{V}{Q} P_e = 45.6\, Wh$$

Irrigation water flow: Similar to the case of domestic tap water flow, we can estimate the hydraulic power P_h, the electrical power P_e and the daily electrical energy E that could be generated form the pumping station.

From formula (1), the hydraulic power P_h is estimated: $0P_h = P.Q = 476.9\, W$.

Formula (2) is used to calculate the electrical power generated by the turbine from the hydraulic power.

$$P_e = \eta_{Tot} P_h = 476.9 \text{ x } 0.8 = 381.5 \text{ W}$$

Then, the electrical energy *E* that could be produced per day is calculated:

$$E = \frac{V}{Q} P_e = 2266.45\, Wh \simeq 2.27\, kWh$$

DISCUSSION

In the case of domestic tap water flow, if we consider common smart phones equipped with battery capacity of 1500 mAh and a voltage of 3.7 V, the estimated daily electrical energy is enough for charging more than eight (8) of them. Within a year the total electrical energy that could be generated from domestic tap water flow is~16.6 kWh. Besides, in a household with domestic commercial activities which use water (examples of laundry, cereal transformation…) and community centres (school, mosque…) the electrical energy that could be generated may be significantly greater. This energy could improve the availability of electricity and contribute to reduce energy bills for households. Agriculture irrigation involve more volume of water. In the example of the small farm considered in this study, we can notice that the generated electrical energy per day is already greater enough and could be considered for an autonomous average household in isolated site. In fact, according to the African Development Bank Group, in 2022 the electrical consumption per person in sub-saharan of Africa is 180kWh/year, which is equivalent to ~0.5 kWh/day. Therefore, the example of irrigation studied above could meet electrical needs of 4 persons at least.

CONCLUSION

In this study, the possibility of generating electricity from domestic tap and irrigation water flow is demonstrated. Thanks to affordability of energy storage solutions and energy efficiency of many basic devices, we estimate that it is the appropriate time to consider micro hydroelectrical power plants on domestic water taps as well as on agriculture irrigation valves. In developing countries, these power plants could play the same role as solar panels and contribute to improve access to electricity. Since agriculture irrigation involve relative high flow rate and volume of water, it is meaningful to consider a production of electricity for small local community use or connection to the grid. It is also important to underline that the solutions presented in this study are environment friendly because they consist in recovering energy which was intended to be lost. Finally, this work is limited to a theoretical evaluation of the quantity of energy that could be generated from domestic and irrigation water networks. Moving forward from this work, an experimental study could be carried out in order to precisely measure the part of energy that could be recovered from the studied sources.

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