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# Comparison of cylindrical and conical basins with optimum position of runner: Gravitational water vortex power plant ☆

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ABSTRACT

Demand of energy is ever increasing, especially in developing countries. Renewable energy such as hydropower has become one of the most demanded sources of energy for its clean generation. Low head hydropower plant is demanded in area which cannot see grid extension due to difficult geographical terrain and other reasons. Gravitational water vortex power plant is one of such low head turbine in which the mechanical energy of free surface flowing water is converted to kinetic energy by tangentially passing the water to a basin, which forms a water vortex. This study is the analysis of different basin structures which has ability to form a gravitational vortex stream from low head, low flow water streams with the optimum runner position in the basin to maximize the output power. The analysis was first carried out by development of the model using CAD software, SolidWorks and it was simulated in commercial CFD code ANSYS Fluent for the measurement of velocity. Secondly, the result so obtained was experimentally verified by measuring the output power.



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## 1. Introduction

Water energy being a clean, cheap and environment friendly source of power generation is of great importance for sustainable future; being aware of this fact, still major of the hydro energy is under-utilized [8].There are mainly two approaches to harness

☆You tube video of project: https://www.youtube.com/watch?v=iMSTpjDIF5M.

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energy from water, namely, hydrostatic and hydrokinetic methods. Hydrostatic approach is the conventional way of producing electricity by storing water in reservoirs to create a pressure head and extracting the potential energy of water through suitable turbomachinery [11]. In hydrokinetic approach, the kinetic energy inside the flowing water is directly converted into electricity by relatively small scale turbines without impoundment and with almost no head [10].

Gravitational water vortex turbine is an ultra-low head turbine which can operate in as low head range of 0.7–2 m with similar yield as conventional hydroelectric turbines used for production of renewable energy characterized with positive environmental yield [24]. Austrian Engineer Franz Zotloterer invented this power plant while he was looking for an efficient way to aerate water. The gravitational vortex is a milestone in hydrodynamic development because in the past we needed energy to aerate water, but now this technique uses a water aeration process to produce electrical energy [21].

The water passes through a large, straight inlet through the channel and then passes tangentially into a round basin, which forms a powerful vortex; an exit hole is made at the bottom of the basin through which the vortex finds its outlet [14]. The turbine does not work on pressure differential but on the dynamic force of the vortex; not only does this power plant produce a useful output of electricity, it also aerates the water in a gentle way [19]. Said aim is achieved by as hydroelectric power plant which supports the formation of a stable gravitational vortex which tends to be formed also in the upper reaches directly in front of the turbine inlet of conventional river stations as a lost vortex and is therefore prevented as much as possible there. The inventive hydroelectric plant, however, ensures that the necessary current-related conditions are fulfilled for reinforcing the rotational movement of the water, which is created when the water flows off, in an unimpeded manner into a stable gravitational vortex without using pressure lines and directing devices. A turbine that rotates in a coaxial manner within the gravitational vortex and is impinged upon along the entire circumference thereof withdraws rotational energy from the gravitational vortex, which is converted into electric power in a generator[24].

In addition, gravitational vortex power plant is found to be advantageous due to the following properties of water vortex:

a. Increases the water surface area.
b. Maximizes the velocity of flow on the water surface area.
c. Disseminates homogenously contaminants in the water.
d. Increases the contact surface of the disseminate contaminants for microorganisms and water plants.
e. Aerates the water naturally, because of the high velocity of the flow on the water surface area.
f. Increase the heat of evaporation so water can reduce the temperature itself at rising temperatures in summer.
g. Concentrates dense water (water at 40C) in the ring shaped center to ensure the survival of microorganisms as long as possible [24].
h. The BOD removal efficiency of aerobic biological treatment processes depends on a number of factors including (but not limited to): influent BOD loading, F:M ratio, temperature, nutrient levels, and dissolved oxygen (DO) concentrations [17]. Through the creation of vortex dissolved oxygen concentration can be improved.

## 2. Nepal and its perspective

Nepal boasts snowy mountains (Himalayan range) in the North which acts as a perennial source for many free flowing rivers establishing the country as second richest in water resources in the world after Brazil [2]. About 6000 rivers with total length of around 45,000 km and an annual discharge of 174 billion cubic meters are available in the nation [18].Nepal has about 83,000 MW of economically exploitable resources, but only 650 MW have been developed so far; about 63% of Nepalese households lack access to electricity and depend on oil-based or renewable energy alternatives; the disparity in access is stark, with almost 90% of the urban population connected, but less than 30% of the rural population [3].

The majority of Nepal's rural populations have been meeting their energy needs (mainly for cooking and heating) by burning various forms of biomass (forest wood, crop residues and dried animal dung) in open hearths or in traditional stoves. In Nepal, the campaign of rural electrification started more than 40 years ago; however, the provision of electricity to remote, rural communities is unrealistic and challenging [12]. The marginal cost of grid extension is greatly increased in rural areas by physical isolation, lower electricity loads, high upfront equipment costs, higher costs of supply and maintenance and low population density with scattered low-income consumers which results linking of rural areas to national electricity grid difficult and implausible [1,4,15]. Development and implications of low head turbines thus may be a good alternative to light up such areas.

## 3. Study of past researches

Mulligan and Casserly did their research project on “Design and optimization of a water vortex hydropower plant” carried out at the Institute of Technology, Sligo in Civil Engineering [13]. This research concludes that optimum vortex strength occurs within the range of orifice diameter to tank diameter ratios ($d/D$) of 14–18% for low and high head sites, respectively. Thus, for cylindrical basin, to maximize the power output, the range of orifice diameter to basin diameter ratios lies within 14–18%.

Bajracharya and Chaulagai focused on developing innovative low head water turbine for free flowing streams suitable for micro-hydropower in Terai region of Nepal [5]. In this study, water vortex was created by flowing water through an open channel to a cylindrical structure having a bottom whole outlet. The research concluded that for a fixed discharge condition, the height of basin, diameter and bottom exit hole are fixed, i.e., the basin geometry depends on the discharge supplied. This study suggests that, in sufficient flow condition, vortex minimum diameter is at bottom level and is always smaller the exit hole.

Wanchat and Suntivarakorn studied the effect of basin structure in formation of water vortex stream [21,22]. Their study indicates the important parameters which can determine the water free vortex kinetic energy and vortex configuration and they include the height of water, the orifice diameter, conditions at the inlet and the basin configuration. It was found that a cylindrical tank with an orifice at the bottom center with the incoming flow guided by a plate is the most suitable configuration to create the kinetic energy water vortex.

The power production varies along with head and flow. Therefore, for a given head and flow the different geometrical parameters that can be varied of conical basin for gravitational water vortex power plant are: (i) basin opening, (ii) basin diameter (iii) notch length (iv) Canal Height and (v) Cone Angle and among these parameters for a given basin diameter, all other parameters has significant contribution for the change in velocity except notch angle [9]. Although the objective of study with Panditet al. is different with similar principle, their study also suggests that the geometry of hydrocyclones is very sensitive to its hydraulic and particle removal capability [16].