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A Review on Eco-Friendly Production of Electricity Using Vortex Turbine

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***Abstract*:- Whirlpool turbine is one of the options for rural electrification, stands out for its exceptional ability to produce energy continuously at the given rated stream of water. The only way to address the growing energy dilemma is to use renewable resources. Whirlpool Hydropower Generator is one of the developing improvements that have extraordinary consideration worldwide. It is an addition to the group of ultra-low head hydropower generating. In Whirlpool Hydropower Generator, a coaxial turbine and generator are paired with an artificially created vortex to produce power. The goal of this work is to develop a whirlpool- and vortex-powered turbine that can generate electricity from conventional canal systems. It is a low-water head turbine with an internal submersible generator that will produce energy through a canal system. The turbine's robustness and adaptability, combined with an independent grid-connected system, allow it to operate continuously. Removing the need for heavily constructed high-water level reservoirs for power generation, shifting conventional water flow axis to a natural vertical Whirlpool Flow, while minimizing harm to marine life. Moreover, this prototype will utilize in the canal systems for effective power generation as it can be installed at small places like remote areas.**

Keywords: Whirlpool turbine, vortex turbine, gravitational turbine, low head turbine.

1. INTRODUCTION

The most significant source of electricity generation from renewable energy sources is water, which has been used for ages. One of the primary necessities of living in the modern world is electricity. Any nation's fundamental economic structure might be badly harmed by its lack. In recent decades, there has been a fast increase in population, urbanization, and industry, which has led to an imbalance between the demand for and supply of electric power [1]. The traditional hydroelectric power generation techniques demand a lot of resources and civil labor. Even if these traditional plants produce energy more effectively, they are unable to supply enough power to meet demand in remote and distant places. Researchers have begun making improvements in Hydropower Plants to address this issue [2]. These tiny hydroelectric generators can be incorporated into common rivers, canals, and irrigation networks. The typical hydropower plants get their return on investment in 15 years. These mini-hydro plants only last 7 years because of their greater construction cost [3], and are capturing the interest of researchers and investors with so many possible key locations available [1]. The Whirlpool Vortex Flow concept is used by the majority of these small hydropower units. Whereas a whirlpool is a whirling column of water that forms when two opposing water currents collide or run against a barrier [4]. When we drain water from something, primarily from our sink drains and baths. Vortexes are whirlpools with a proper downdraft that move in a vertical downward spiral as a result of gravity. As a result, Whirlpool Vortex Turbine Systems was named [5]. These low water head systems demand a continual flow of water. In order to create an artificial whirlpool vortex from which to derive the turbine blades, they essentially exploit gravity [6]. The turbine has a vertical axis cross-flow, and it uses this to generate hydropower from canal systems. Utilizing gravity to the benefit the turbine that is both economical with cheap installation costs and environmentally acceptable [7]. A certain system -geometry that directs the water flow motion in a vertical conical manner results in the creation of artificial whirlpool vortices. Consequently, a vertical water whirlpool vortex flow was produced [8]. These small power plants have an output range of 10 to 100 kW and a relatively small head flow differential of 0.8 to 2.0 m [9]. The turbine blade should be twisted to 60 degrees, rather than the older typical straight blade, it has been found after multiple experiments. In other words, the curvature angle of the turbine blade gradually increases the performance curve. The lowest point of the performance curve at 60 degrees, starting from a vertical 90-degree angle, has been proven to be the most effective for this particular scenario. Additionally, two factors need to be taken into consideration when building these turbine blades [10]. The first, material utilized must be lightweight in order to have a low activation rotation force and still be economical [2]. these projects [9],[4] will be very helpful in providing consumers with electricity at a much lower cost, and is far more effective than steel for the purpose of producing hydroelectricity [11]. Marine life is still at risk from aluminum blades Due to this, it was suggested that PVC (Poly-Vinyl Chloride) material be used to manufacture the turbine blades. It is not only resilient and durable, being both lightweight and flexible, but it also provides the least threat to fish and other aquatic creatures [12].

1.1. BASIC SYSTEM SUMMARY

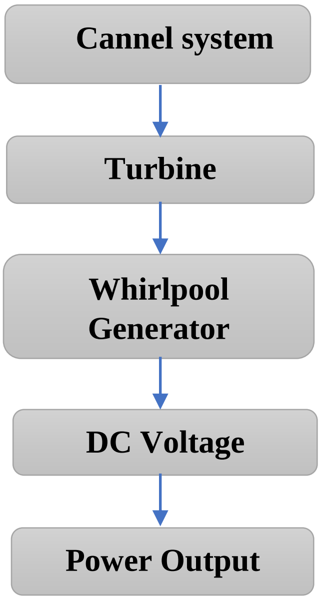

Fig.1 Basic System Flowchart Diagram.

2. SYSTEM MODELLING

CAD software was used by the researchers [4],[13],[5] for designing purposes to create 3D models of turbines. The primary goal is to design the performance curve which had the starting and ending angles of 90° and 60°, respectively. Such that the water vortex can be used as quickly as possible.

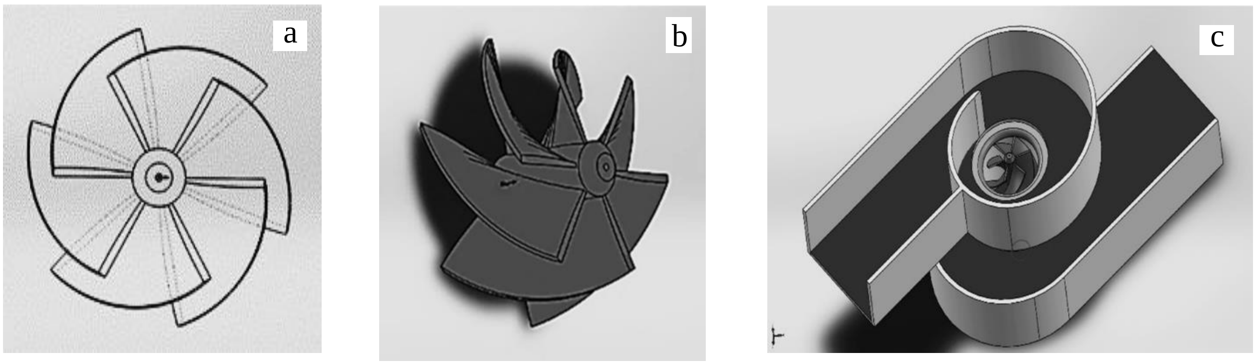

Fig.2 (a) Top View of Whirlpool turbine (b) Whirlpool Turbine 3D model and (c) Whirlpool Hydropower Generator System Assembly [1],[2],[14].

3. ANSYS SIMULATION

ANSYS simulation was used by the researchers [15],[16],[17] for the Motional rotation of the turbine blades. The simulation was done using the ANSYS Work Bench Simulation Software, which can be used to generate simulations that examine a product's resiliency, fluid movements, and electromagnetic properties.

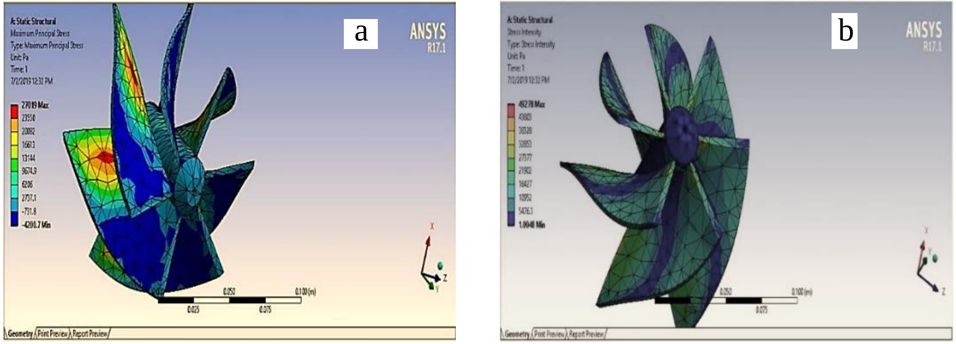

Fig.3 (a) Analysis of stress in Turbine Blades and (b) Pressure Analysis in Turbine Blades [1].

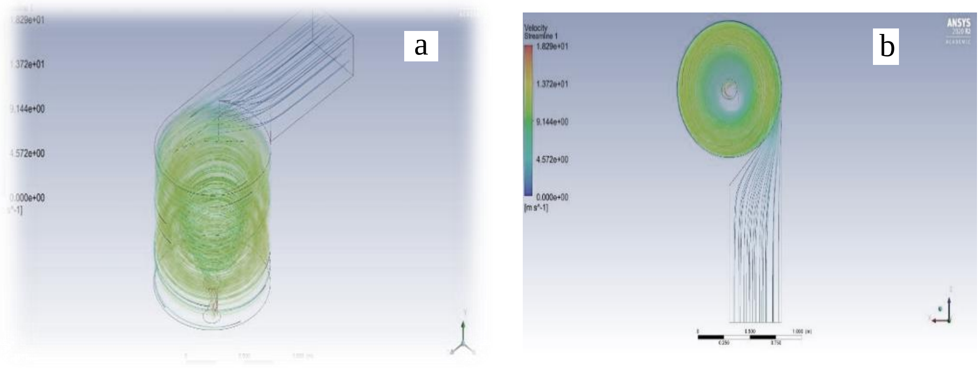

Fig.4 Velocity Streamline Flow (a) Isometric View and (b) Top View [1],[17].

Figures 4 (a) and (b) with the flow of the stream routes indicated in the flow direction show the streamlines. This velocity streamline serves as an example of the vortex formation, which is shown by the streamline's conical shape. The air cone's surface becomes less as the streamline gradually falls. Descending to the chamber's base, where the stream routes are completely asymmetric, and the streamlines flow radially. The color scales show the magnitude of the velocity, which can be used to determine the streamlines' velocities at various locations.

The pressure contour plots presented from the top view and based on various ZX plane altitudes in Figure 5 provide a clearer picture of the vortex production along with its location. From the chamber's top to bottom, an air-core formation is seen to be gradually reducing in Figure 5. That makes it easier to comprehend that the core's structure is conical and that the core's location fluctuates according to the chamber's height [17].

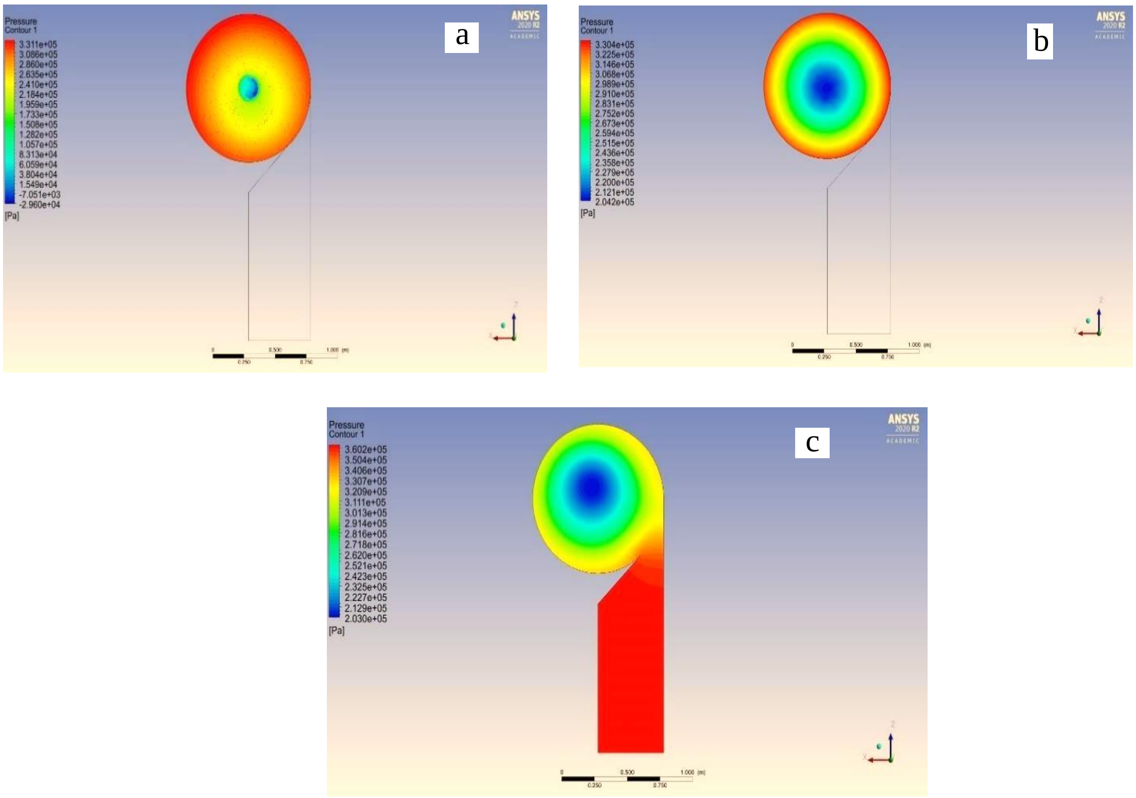

Fig.5 Pressure Contour from bottom at (a) 0%, (b) 50% and (c) 100% [17].

Figures 6 (a) and (b) present the models of vortex production in the form of the lambda-2 criterion. The lambda 2 criterion simply concerns how turbulent structures can be visualized by proper iso-surfaces of lambda 2. Figures 6 (a) and (b) show the models of best vortex Formation [18].

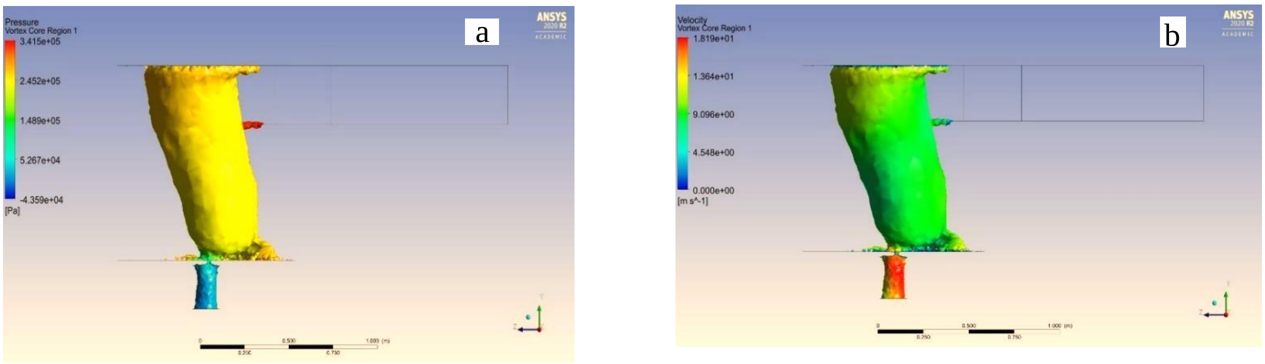

Fig.6 Vortex Formation: (a) Pressure and (b) Velocity [17].

To get a good vortex formation, The pressure between the intake and output sections will differ. Figure 6 (a) shows the static pressure of the channel decreases as the velocity increases in the channel contraction section. At the tunnel's contraction segment, the pressure has increase, When the tunnel is about to contract at the outlet region, the fluid flow hits its walls of contracted region, and the fluid flow's velocity drops to zero, generating a zone of stagnation that raises the overall pressure.

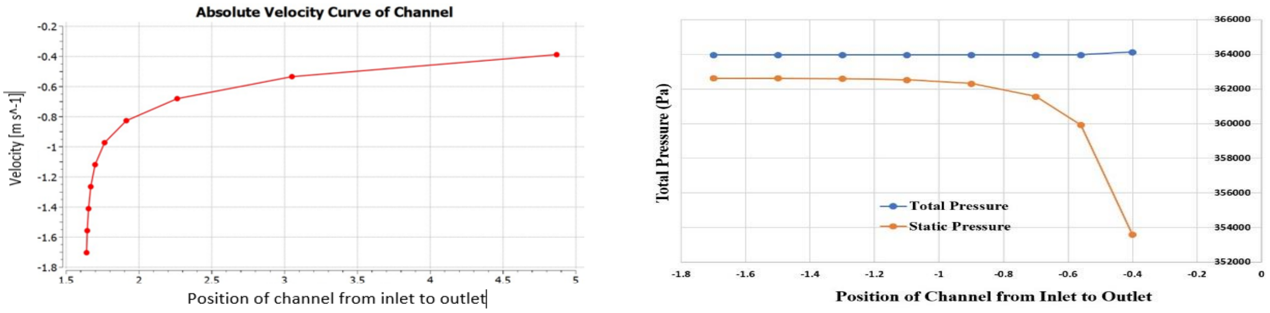

Fig.6 (a) Absolute velocity curve of the channel, and (b) Pressure curve of the channel [17].

4. POWER CALCULATIONS

The water turbines transform the mechanical energy that the fast-moving water exerts on the turbine blades into electrical energy. A generator is turned for this energy conversion by a rotating turbine, which results in an output of electricity. Efficiency is computed and assessed for checking purposes using both numerical and experimental Results. The numerical values were obtained using computer simulations [19],[1] in accordance with the material specifications indicated in the Table 1 and Table 2. whereas the experimental values were obtained through multiple real-time testing of our hardware setup [20],[21],[16]. numerical and experimental results had been computed and recorded.

Table 1. Numerical and Experimental Results of Voltage, Current and Power [1].

Sl. No.	Parameters	Numerical Results	Experimental Results
1	Voltage (V)	12 volts	13.27 volts
2	Current (I)	0.1 amps	0.053 amps
3	Power (S)	1.2 watts	0.70332 watts

Table 2. DC bulbs of different wattages [22].

Sl. No.	Bulb Load (W)	Angle of Wet Area (degrees)	Measured Voltage (V)	Measured Current (A)
1	No Load	28	0	1
2	13	9.9	1.18	2
3	16	9.9	1.31	3
4	20	2.8	7.14	4
5	No Load	15	28	0
6	7.4	15	14.6	0.51
7	11.1	15	13.6	0.82
8	18.5	15	12.5	1.48
9	11.1	20	14	0.79
10	18.5	20	13	1.42

As dummy loads, DC lamps of various wattages were connected to the generator's output terminals. The loads' voltage and current outputs are measured by a microcontroller control unit. The Table 1 and Table 2 displays the outcomes that were attained.

4.1. POWER GENERATION

The power from the flow of water falling to the turbine can be expressed in [23] as:

$P_{th} = P_{water}\, q\, g\, h$

Q = water flow ($\frac{m^3}{s}$)

G = acceleration of gravity ($\frac{9.81m}{s^2}$)

H = falling height (m)

The efficiency of the turbine is calculated as[2]:

$P_a = \mu P_q g h$

μ = Efficiency Range

P_a = power available (W)

$W = PVGH$

$where\ v = volume\ of\ (m^3)$

Apparent power is a measure of alternating current (AC) power that is computed by multiplying current by voltage.
Apparent Power (S) = V x I = 12 x 0.1 = 1.2 (Watts)

The power that expresses in physical phenomena like electromagnetic radiation, acoustic waves, or mechanical phenomena is true power.
True Power (P) = v x i = 13.37 x 0.053 = 0.7332 (Watts)

Efficiency:
η = (True Power/Apparent Power) *100
= (P / S) * 100
Efficiency = 58.6%.

5. CONCLUSION

This paper proposes an overview of the whirlpool generation unit which is beneficial due to the current economic barriers and rural area electricity consumption demand. This whirlpool turbine can be designed and developed for a hydro system with a low water head. The vortex turbine is incredibly effective at producing electricity. A smaller blade size results in a higher rotating speed for a given geometrical design of turbine and flow rates. The numerical and experimental findings revealed that it is a simpler and more affordable alternative for rural areas where traditional transmission and distribution systems face a number of operational and financial challenges. It is environmentally friendly and has a maximum power capacity of more than 30 homes. These small power plants have the capacity to generate 10 - 100 kW with a relatively modest head differential of 0.8 - 2.0 meters.

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