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Screw Shaft Flywheel Stabilizing Hydro Turbine for Run of River Installations

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Abstract: **Energy demand is on a steady increase due to population growth and economic pursuits which depend critically on energy. Nigeria boasts of many large and small rivers, but many rivers with low head and good flow are just flowing without being used for power generation for many years. The practice hitherto has been the procurement and installation of very costly gigantic hydropower stations requiring dams to hold water and create very enormous heads to drive the high capacity turbines. The Energy Commission of Nigeria, through its Centres in Bauchi and Nsukka devices a design to harness energy from flowing rivers without dam installations. This project proposes a run off river system and employs a reaction turbine of the version used in Archimedean screw pumps to proffer a holistic contraption to harness the energy of flowing water as the water continuously pushes the baffles all along the length of the screw shaft. A flywheel is incorporated at the shaft end to cushion fluctuations and maintain steady motion. This is a novel technology for energy provision especially in the rural areas where small rivers abound.**

Keywords: **Power, Hydro, River, Turbine, Reaction, Screw, Shaft.**

I. INTRODUCTION

Conventional hydropower plants employ dams and impoundments to harness the potential energy stored in reservoirs by creating a hydraulic head differential which is eventually converted into electrical energy through suitable turbo machinery (Ladokun *et al.*, 2013). All existing big hydropower stations in Nigeria employ dams to achieve pressure heads for energy harnessing. The turbines are generally Impulse turbines known to harness enormous energy from high heads. Contrary to apparent benefits, the large scale hydroelectric development produces a broad range of environmental impacts. Chief among these impacts are landscape destruction, contamination of food webs by mercury, and possibly the evolution of greenhouse gases (Rosenberg *et al.*, 1995). Consequently, the high cost of large hydropower installations, loss of aquatic habit, harm to fish populations as well as significant change in natural flow regimes and deterioration of the landscape has led to alternative development of Run-off River (ROR) and Direct River (DR) systems which maintain ecological stability while providing portable power to remote locations. ROR installation is where the water is diverted upstream at a natural gradient and used to drive a typically small turbine. The DR is where the Hydro turbine is installed on stanchions casted on the riverbed allowing the force of flowing water to drive the turbine. These novel machines come in as Small, Micro and Pico Hydro turbines accompanied by prevalent low speed of hydro turbines. Small hydro plants do not suffer from such environmental and social problems as larger ones generally due to the scale of the technology and the insignificant storage of water. Normally these schemes do not form a barrier to the passage of aquatic life, especially fish.

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ROR hydro plants have become more important in recent years. Such plants are characterized by the small or zero storage capacity of the head pond and therefore the generated energy depends to a great extent on the available flow in the river. Typical advantage of ROR over conventional storage systems is that it allows harnessing the energy associated with water flows for other uses, such as water supply or irrigation, or the environmental minimum flows (Sarasúa *et al.*, 2014). Small, Micro and Pico hydro as achieved through ROR and DR; engender positive social impacts. There is a greater potential for active participation of the beneficiaries and the associated social benefits from rural electrification using these smaller hydro-power than with other technologies. In addition, since large damming is unnecessary, the displacement of inhabitants and restructuring of livelihoods are avoided. (Edeoja *et al.*, 2015).

The primary electrical and mechanical components of a hydro plant are the turbine and the alternator. The turbine is the shaft-baffle assembly rotated by the force of moving water. The alternator or generator is the electrical component that generates electricity when coupled to a turbine. It is the machine that converts the mechanical energy of the turbine to electrical energy. Conventional impulse and reaction turbines have been employed in power engineering. This work designs a reaction type turbine in the form of a screw shaft that is aided by a flywheel to smoothen fluctuations and achieve steady motion. The introduction of a reaction turbine of the version used in Archimedean screw pumps to holistically harness the energy of flowing water as the water continuously pushes the baffles all along the length of the screw shaft appear to be the needed solution for energy provision in Nigeria and other developing countries with abundant small rivers,. The shaft is aided by a flywheel to cushion fluctuations and maintain steady motion.

II. AIMS AND OBJECTIVES

This innovation is a need-driven research product for harnessing energies from the numerous low head rivers and streams in Nigeria. Nigeria needs a technology that can be easily built, utilized and maintained by the available technicians and technologists thereby reducing the importation of machinery, spare parts and the accompanying specialized technicians. The objective of the invention is to enhance renewable energy harnessing by creating a cost-effective completely indigenous and domesticated Small hydro turbine to harness energies from flowing rivers, stream and narrow water ways which abound in Nigeria. Screw Shaft Flywheel Stabilizing Hydro Turbine is a medium precision machine which can be fabricated, installed and maintained by most Nigerian technicians and technologists.

III. TURBINE TYPES

There are two main types of hydropower turbines: reaction and impulse. The type of hydropower turbine selected for a project is based on the height of standing water, referred to as "head"—and the flow, or volume of water over time, at the site. Impulse and Reaction turbines are discussed below:

A. Impulse Turbine

An impulse turbine generally uses the velocity of the water to move the runner and discharges at atmospheric pressure. A water stream hits each bucket on the runner. With no suction on the down side of the turbine, the water flows out at the bottom of the turbine housing after hitting the runner. An impulse turbine is generally suitable for high-head, low-flow applications. The two main types of impulse turbine are Pelton and cross-flow turbines. Impulse turbines are most efficient for high head and low flow sites that are used for situations with heads ranging from 6 feet to 600 feet. These types of turbines generally are simple design and inexpensive. The two main types of impulse turbine are Pelton and cross-flow turbines.

i. Pelton Turbine: In a Pelton turbine (Plate 1), water jets from nozzles strike the double cupped buckets attached to the wheel, arranged on a circumference of a runner or wheel, causing a force that rotates the wheel at high efficiency rates of 70 to 90 percent. Pelton turbines are suited for high head, low flow applications. Pelton turbines can also be used for small hydropower systems. For small systems, a single water jet is typically used. (Elbatran *et al.*, 2015).

ii. Cross-flow turbine: A cross-flow turbine (Plate 2), is shaped like a drum and uses an extended, rectangular-section nozzle directed against curved vanes on a cylindrically shaped runner.

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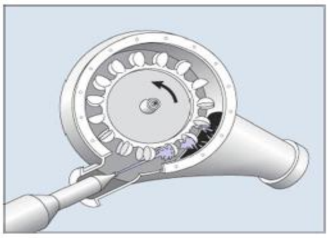

Plate 1: Pelton Wheel

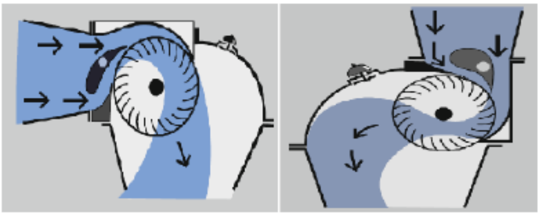

Plate 2: Cross-flow turbine in horizontal and vertical orientations

The cross-flow turbine allows the water to flow through the blades twice. During the first pass, water flows from the outside of the blades to the inside; the second pass is from the inside back out. These types of turbines can be used both in horizontal and vertical orientations.

B. Reaction Turbines

A reaction turbine generates power from the combined forces of pressure and moving water. A runner is placed directly in the water stream, allowing water to flow over the blades rather than striking each individually. Reaction turbines are generally used for sites with lower head and higher flows and are the most common type currently used in the United States. In the slow operating speed, the efficiency of reaction turbines is better than the impulse turbines. Reaction turbines are a class of "zero head" hydropower which extracts energy from the velocity of flowing water to drive a generator. They are in-Stream, or water current energy conversion technologies utilizing the kinetic energy of rivers, streams, tidal currents or other man-made waterways for generation of electricity. Installation of reaction turbines do not involve any construction that alters the natural pathway of moving water. Hence, it is more environmentally friendly (Ladokun *et al.*, 2013). The two most common types of reaction turbines are Propeller turbine and Francis turbine.

i. Propeller turbine: A propeller turbine generally has a runner with three to six blades. Water contacts all of the blades constantly. Plate 3 depicts the Kaplan turbine which is a propeller turbine. The concept is that when a boat propeller is housed in a pipe and large flow of water goes through to drive the turbine, energy can be harnessed if the propeller shaft is connected to an alternator. Through the pipe, the pressure is constant to ensure runner stability. The pitch of the blades may be fixed or adjustable. The major components besides the runner are a scroll case, wicket gates, and a draft tube. There are several different types of propeller turbines but the most popular is the Kaplan turbine. It generally has a runner with three to six blades. Water contacts all of the blades constantly. This turbine was developed by Austrian inventor Viktor Kaplan in 1913 (Elbatran et al., (2015). The hub includes mechanism to adjust blades and wicket gates angles.

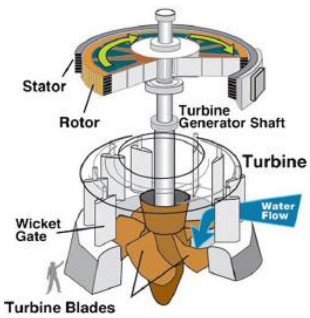

Plate 3: Kaplan turbine

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ii. Francis Turbines: A Francis turbine is the most used hydro-turbine in advanced countries; it has a radial or mixed radial/axial flow runner which is most commonly mounted in a spiral casing with internal adjustable guide vanes. Water is introduced just above the runner and all around it and then falls through, causing it to spin. Besides the runner, the other major components are a scroll case, wicket gates, and a draft tube. The cross-sectional view of a Francis turbine is shown in Figure Plate 4.

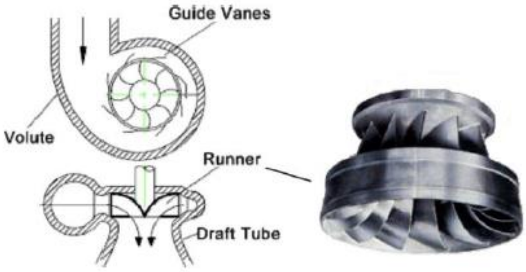

Plate 4: Francis turbine

IV. FLYWHEEL

A flywheel (Plate 5) is a rotating disk that stores energy as kinetic energy. The faster the flywheel spins the more kinetic energy it stores. The concept of a flywheel is as old as the axe grinder's wheel, but could very well hold the key to tomorrow's problems of efficient energy storage.

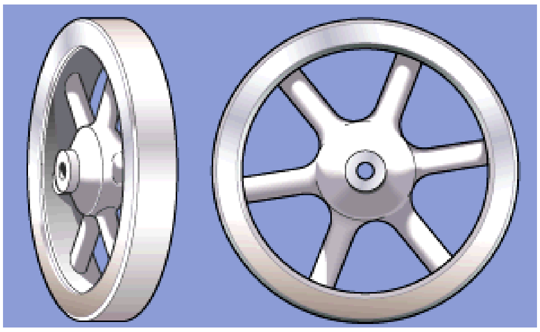

Plate 5: Flywheel

A simple example of a flywheel is a solid, flat rotating disk. A flywheel is an inertial energy-storage device. It absorbs mechanical energy and serves as a reservoir, storing energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than the supply. The main function of a flywheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations. If the source of the driving torque or load torque is fluctuating in nature, then a flywheel is usually called for. Many machines have load patterns that cause the torque time function to vary over the cycle. Internal combustion engines with one or two cylinders are a typical example. Piston compressors, punch presses, rock crushers, etc. are the other systems that have flywheels. Due to its high density, low cost and excellent machinability, gray cast iron ASTM 30 is often used to make the flywheel, whose properties are listed in Table 1. (Bawane *et al*., 2012).

Table 1: Material and Properties of Conventional Flywheel

Material, class, specification	Gray cast iron, ASTM 30, SAE 111
Ultimate strength	Tension, Sut = 214 Mpa; Shear sut = 303 MPa
Torsional/Shear strength	276 MPa
Modulus of elasticity	Tension, E = 101 GPa; Shear, G = 41 GPa
Density	7510 kg/m^3
Poisson's ratio	0.23

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The flywheel can be used as an energy reservoir, with energy being supplied at a slow constant rate or when it is available and being withdrawn when desired. A flywheel might, for example, be used to give good acceleration to an automobile that is underpowered by present standards. Regenerative breaking, power storage for peak-demand periods, and mechanical replacements for battery banks are all potential uses for the flywheel. The high charging and discharging rates of a flywheel system give it an advantage over other portable sources of power, such as batteries. The purpose of energy-storage flywheels is to store as much kinetic energy, $0.5J\omega^2$, as possible. The design of the ordinary flywheel is usually dictated by the allowable diameter, governed by the machine size, and the maximum speed, governed by the practicalities of a speed increasing drive and higher bearing speeds. (Curtis, 1996).

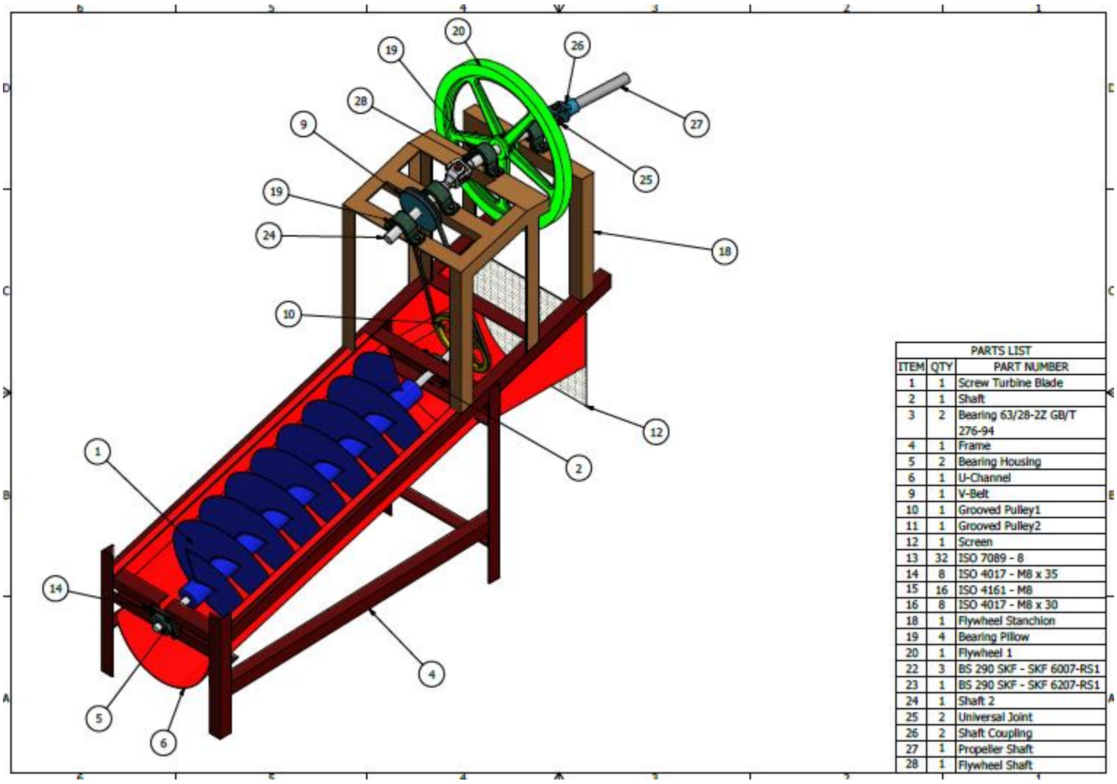
Energy moving in and out of the flywheel can be used to provide temporary and constant power. A flywheel's greatest benefit is in equipment where the main power source is provided in unsteady bursts. By using conservation of energy, the flywheel stores energy as it is being released from the main power source in a surge or burst. As the main source of energy decreases, the energy stored in the flywheel is released. The force of flowing water varies as water flow is usually unsteady. A flywheel is a simple rotating wheel used to store energy and stabilize motion. The kinetic energy stored in a flywheel is proportional to the mass and to the square of its rotational speed according to Eq. (1). (Bolund *et al*., 2007).

$E = \frac{1}{2} Iw^2$ ………….. (1).

Where 'E' is kinetic energy stored in the flywheel, 'I' is moment of inertia and 'w' is the angular velocity of the flywheel.

V. MACHINE DESCRIPTION

Figure 1 displays the isometric view of the machine without the Permanent Magnet (PM) alternator as it is going to be mounted out of the water way while the output shaft of the Flywheel transmits motion to it through chain and sprocket transmission or direct coupling as the case may be. Figure 2 and Figure 3 are the orthographic and exploded views of the machine.



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Screw Turbine Blade
2	1	Shaft
3	2	Bearing 63/28-2Z GB/T 276-94
4	1	Frame
5	2	Bearing Housing
6	1	U-Channel
9	1	V-Belt
10	1	Grooved Pulley1
11	1	Grooved Pulley2
12	1	Screen
13	32	ISO 7089 - 8
14	8	ISO 4017 - M8 x 35
15	16	ISO 4161 - M8
16	8	ISO 4017 - M8 x 30
18	1	Flywheel Stanchion
19	4	Bearing Pillow
20	1	Flywheel 1
22	3	BS 290 SKF - SKF 6007-RS1
23	1	BS 290 SKF - SKF 6207-RS1
24	1	Shaft 2
25	2	Universal Joint
26	2	Shaft Coupling
27	1	Propeller Shaft
28	1	Flywheel Shaft

Figure 1: Isometric view of Screw Shaft Flywheel Stabilizing Hydro Turbine

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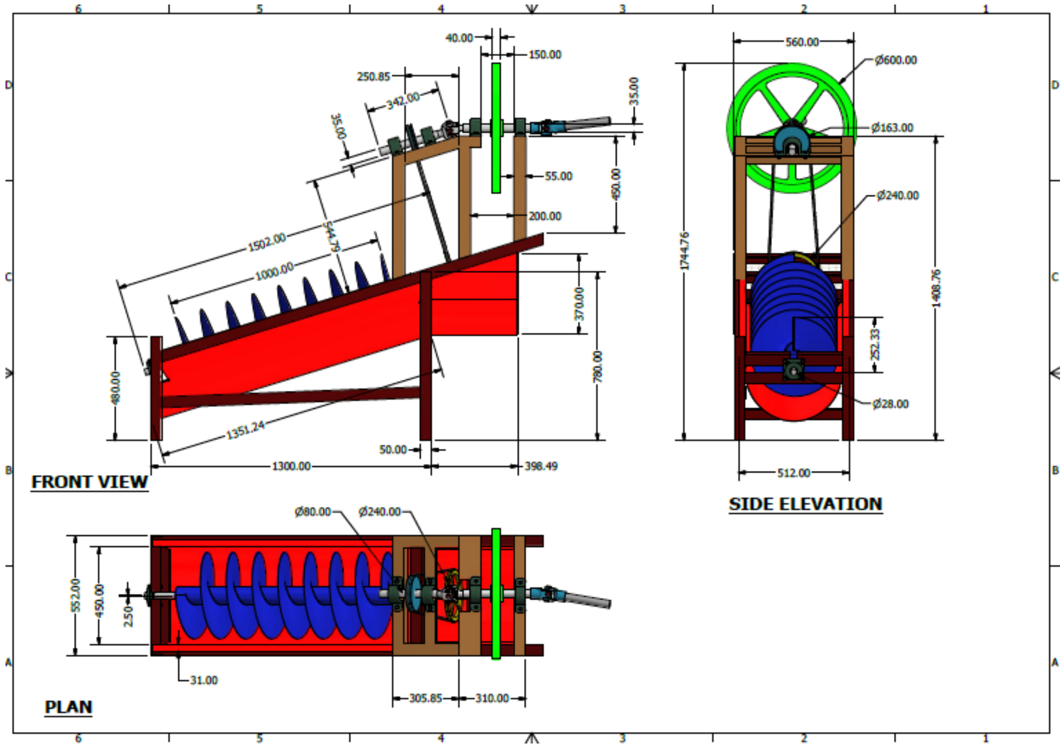
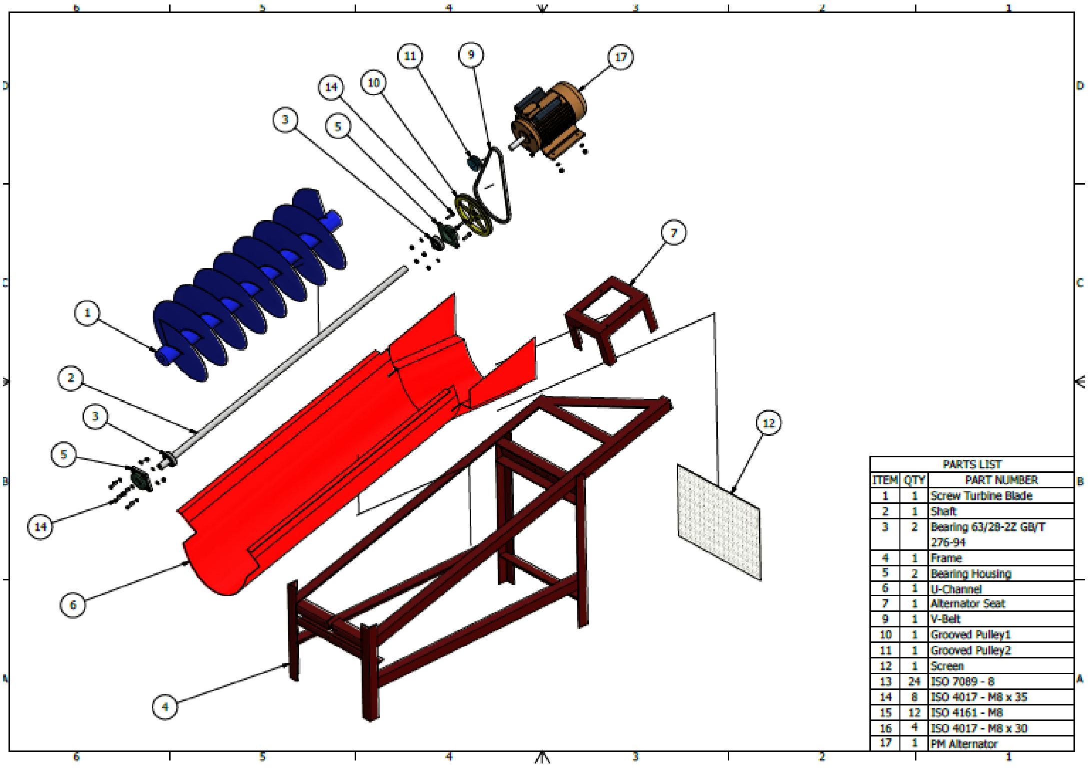


Figure 2: Orthographic view of Screw Shaft Flywheel Stabilizing Hydro Turbine



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Screw Turbine Blade
2	1	Shaft
3	2	Bearing 63/28-2Z GB/T 276-94
4	1	Frame
5	2	Bearing Housing
6	1	U-Channel
7	1	Alternator Seat
9	1	V-Belt
10	1	Grooved Pulley1
11	1	Grooved Pulley2
12	1	Screen
13	24	ISO 7089 - 8
14	8	ISO 4017 - M8 x 35
15	12	ISO 4161 - M8
16	4	ISO 4017 - M8 x 30
17	1	PM Alternator

Figure 3: Exploded view of Screw Shaft Flywheel Stabilizing Hydro Turbine

Figure 4 depicts Screw Shaft Flywheel Stabilizing Hydro Turbine with the Permanent Magnet (PM) alternator afar off as it is mounted out of the water path to avoid contamination and destruction by water. A directional Channel shown in red colour houses a long Screw Shaft on bearings with V-belt transmitting motion to a Flywheel carrying intermediate shaft with an output shaft which transmits motion to the PM alternator.

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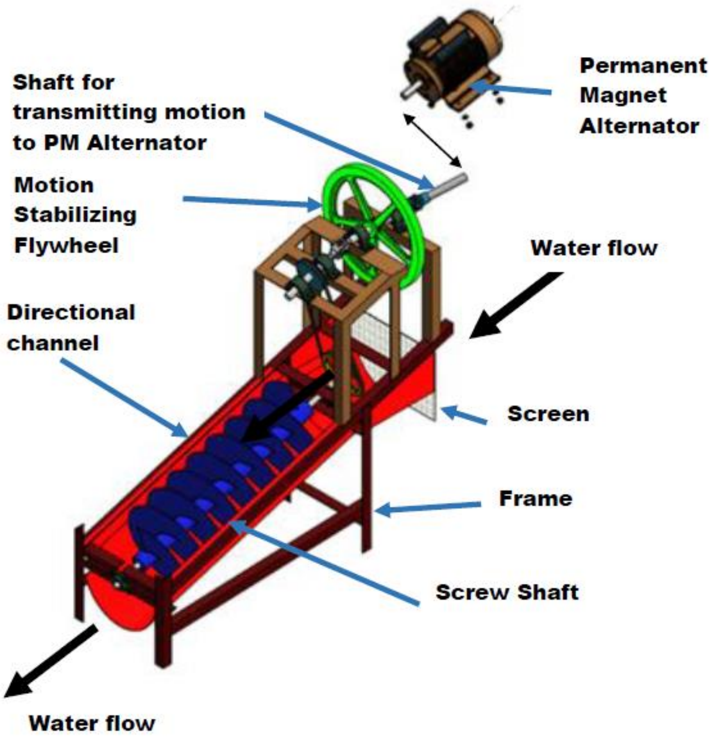

Figure 4: Exploded view of Screw Shaft Flywheel Stabilizing Hydro Turbine with PM Alternator

The permanent magnet alternator has the characteristic property of generating its full kW at between 25-150 rpm unlike conventional alternators which must be rotated to above 1000 rpm to generate electricity. Screw Shaft Flywheel Stabilizing Hydro Turbine is contrived to harness water energy from rivers, streams and narrow water ways. As water flows past the channel, its force on the screw rotate the turbine in the clockwise direction thereby generating electricity by driving a Permanent Magnet (PM) alternator. The drawing shows the Flywheel (painted green) on shaft as it receives motion from the turbine shaft and transmits same to the PM Alternator. The Flywheel helps to stabilize rotating shafts that are subject to alternating pressures. The stabilizing effect comes from the flywheel resisting changes in its rotational speed. Since the water flow through the flow channel is constantly changing, the flywheel conserves energy during surges and releases energy when the flow is reduced thereby stabilizing the motion and ensuring continuous rotation of the PM alternator and electricity generation.

VI. CONCLUSION

By coming up with the novel Screw Shaft Flywheel Stabilizing Hydro Turbine, the National Centre for Petroleum Research and Development (NCPRD) and National Centre for Energy Research and Development (NCERD); both Centres of Energy Commission of Nigeria (ECN), have provided the necessary technology for the proliferation of micro and small hydropower to aid the utilization of renewable energy in remote locations of the country with abundant rivers and streams. It is hoped that the government and individual communities can key into the project as a way of portable power provision in remote villages.

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