International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 10 Issue 6 Series III || June 2021 || PP 01-09

Construction of a Mini-Hydropower Plant

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ABSTRACT: *There are many ways to generate electricity in which Hydroelectric power generation is considered to be one of the environment-centric ways by which electricity can be produced. In today's modern world there is nothing without. Hydroelectric power works to harvest the inherent energy of moving water by directing the water through the turbine converting the energy of the moving water into mechanical energy. The mechanical energy is then converted into electricity in the generator. To choose the appropriate generator for a specific application, the flow rate and pressure head of the water source must be known. Hydropower on a small scale is one of the most cost-effective energy technologies to be considered for rural electrification. Small hydro technology is extremely robust and is also one of the most environmentally acceptable energy technologies available. The position of hydropower plants becomes more and more vital in today's global renewable technologies. It is a cost-effective way to bring electricity to remote villages that are far from transmission lines. It is expected to increase more rapidly than demand for other forms of energy. The objective in which the project has proceeded is to develop a mini-hydro electric power generator that generates electricity sufficient enough to power various power apparatus, machines, labs, and other daily uses for commercial purposes.*

KEYWORDS: *Hydro-Electricity, Hydropower, Rural electrification, small scale turbine, Structural analysis.*

Date of Submission: 06-06-2021 Date of Acceptance: 19-06-2021

I. INTRODUCTION

This paper explores a method used for hydropower generation. Electricity and electrical equipment play a major role in our daily life activities. In the modern days where urbanization is spreading at a rapid pace, the electrification of villages and rural areas plays a major role. Hydroelectricity is a cornerstone of the electric generation power plant which is achieved great significance for the global commercial, economic and environmental concerns. [1]

Hydropower energy is one of the most suitable and renewable forms of energy. Power generation capacity and its transmission are two aspects that define the effectiveness of the generator. Power generation capacity depends on the type of water source like a dam, reservoir, stream, etc..,. [2] The scale of power transmission can be done at a macro level or micro level. Macro-level transmissions require large-scale power generation (816MW -1670 MW) and high-quality wiring to prevent transmission losses. Micro-level power generation involves power generation on a small scale (1.3kW (12 V DC Motor)-5kW).[3] Though the macro-level production of electricity reaches out to a large part of the population, it has its demerits. Macro-level power generation requires large land space and financing for construction, development, and maintenance. But micro-scale power generation involves usage of smaller equipment like dc/ac generator of (1.3kW-5kW) and household electric wiring for small appliances ranging from LEDs to tube lights and fans [4].

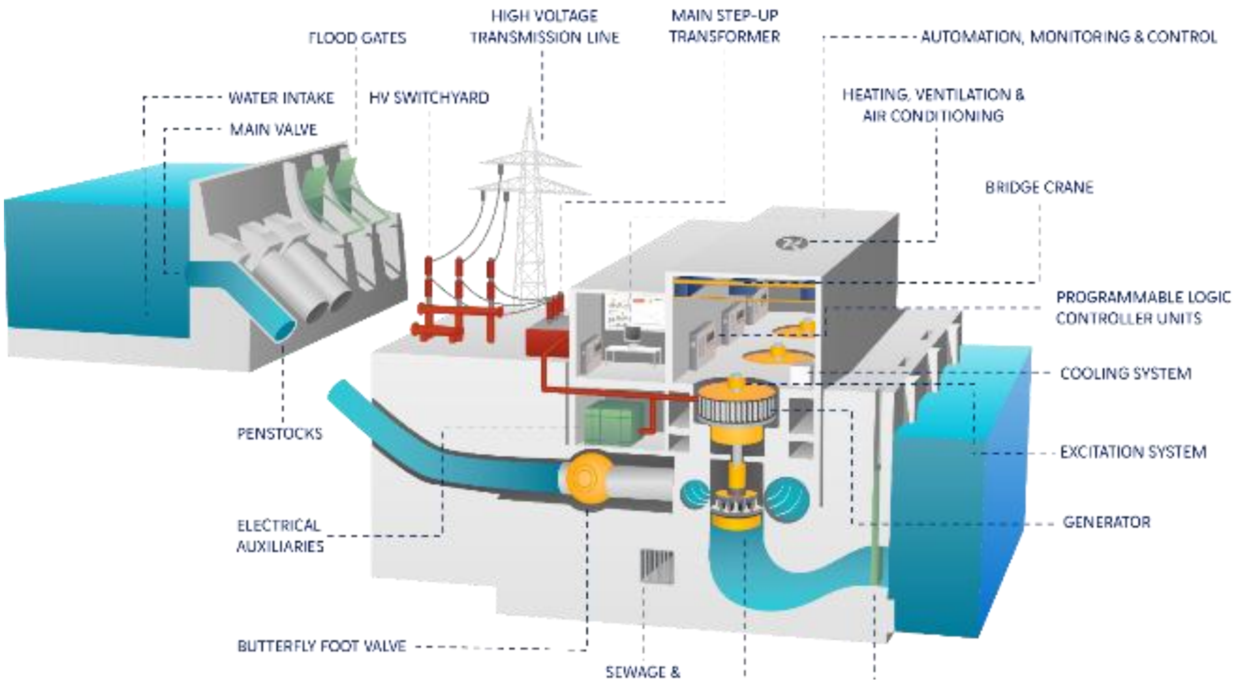

Fig 1: A Hydropower plant

Different methods can be used to produce electricity from hydropower plants. Some of the methods involved in hydropower generation are Dammed reservoir, Run of River (ROR), Pumped storage, and In-stream. The dammed reservoir method is used extensively in spillways of dams or valley regions of rivers [5]. In the pumped storage method, water is pumped to higher land and subsequently, the direction of flow is reversed to generate electricity during the daily peak load period. In-stream technology is similar to Run of River technology where the kinetic energy of river flow is harnessed to generate electricity [6]. The In-Stream method can be used to harness electricity both in the river and also from ocean tides. Run of River is used to harness hydel power specifically from streams and river flow. Run of River functions like a small hydropower station that produces electricity based on available hydrological variations of the site within the natural range of the river. Small hydropower plants attract efficient and reliable investments as they take minimum time for construction and exploit the minimum area. The use of local labor and cost per material and cost per kW is low as compared to other projects [7].

The different types of turbines are classified mainly as reaction turbines and impulse turbines. Impulse turbines are highly efficient for high head and low flow sites (6 ft to 600 ft). The impulse turbine uses the velocity of water to move the runner and water flows out of the bottom of the turbine at atmospheric pressure [8]. This jet strikes the turbine blades due to which the kinetic energy of the water jet is converted into electrical energy. These types of turbines are generally simple in design and inexpensive [9].

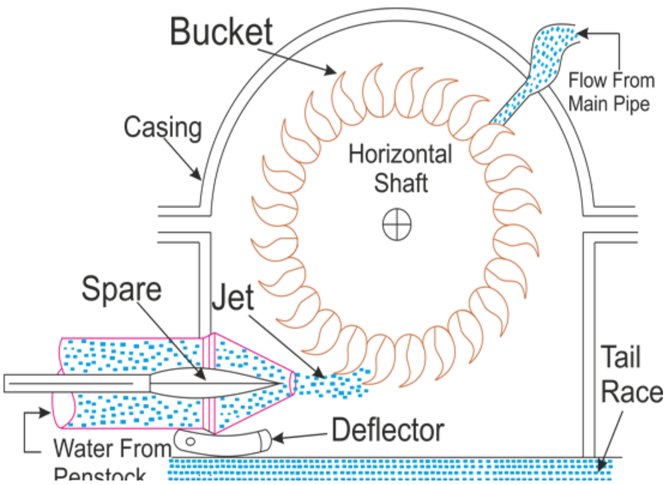

Fig 2: Impulse turbine – Pelton wheel

The different types of impulse turbines used for power generation are the Pelton wheel, Francis turbine, and Kaplan turbine. Kaplan turbine is a low head turbine with its head ranging from 30m to 100m. Francis turbine is a medium head turbine with its head ranging from 150m to 250m. Pelton turbine is a high head-tangential impellor turbine with its head ranging from 400m to 500m [11].

Reaction turbines have a better performance in low head and high flow sites. Blades of this turbine project radially from the periphery of the runner and these blades are mounted in such a way that the spaces between the blades have the shape of the nozzle [10]. A reaction turbine generates power from the combined action of pressure and moving water. In slow operating speed, the efficiency of the reaction turbine is better than an impulse turbine. Also, reaction turbines are more preferred than impulse turbines in regions where high flow is possible with low head [12].

Reaction turbines develop torque by reacting to the gas or fluid's mass. However, rotor diameter affects the maximum rotational speed. Water head and flow rate play an important role in determining the output power of a turbine. Around the globe, there are several small-scale water resources like lakes and small streams that offer a low water head and low flow.[13] With improved and efficient turbine design, this small potential energy can be harvested with high efficiency. Reaction turbines are highly useful in places where low water heads and high flow rates are available.[14] In a reaction turbine, the fluid enters from a larger end and exits from a smaller end to make the blades of the impeller rotate. Now the blades start rotating due to the potential energy of the water.[15] At this time, potential energy stored in water decreases, and the kinetic energy of blades increase due to the increase in angular velocity. A reaction turbine uses a method of propulsion in which reaction produced by the acceleration of a fluid passing through an orifice or nozzle is used to propel the blades.[16]

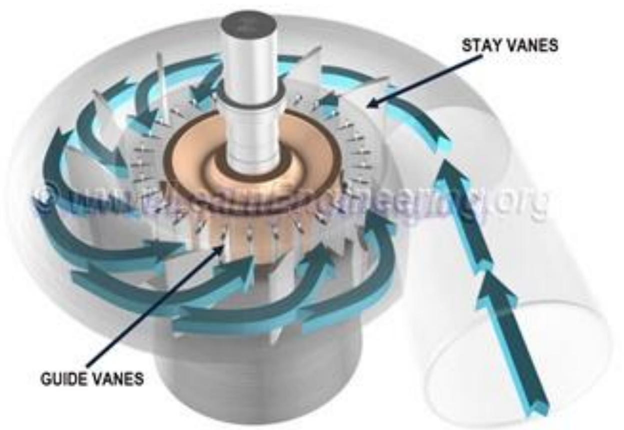

Fig 3: Reaction turbine – Kaplan turbine

II. OBJECTIVE AND RESEARCH

This thesis aims to identify the best method to produce electricity from a flowing stream and then build a method for the production and supply of the produced electricity. Electricity and electrical equipment play a major role in our daily life activities thus in the modern days where urbanization is spreading at a rapid pace, the electrification of villages and rural areas plays a major role. The problem that a lot of people face is the lack of electricity in schools in rural and remote areas. These schools have basic electricity requirements which a small hydropower plant can supply. This paper deals with the ways to construct a hydroelectric power plant for a village school.

The hydroelectric power plant is a cornerstone of the electric generator which is achieved great significance for the global commercial, economic and environmental concerns. Hydropower energy is one of the most suitable and renewable forms of energy. Power generation capacity and its transmission are two aspects that define the effectiveness of the generator. Different methods can be used to produce electricity from hydropower plants. Some of the methods involved in hydropower generation are Dammed reservoir, Run of River (ROR), Pumped storage, and in-stream. The dammed reservoir method is used extensively in spillways of dams or valley regions of rivers. In a stream, technology is similar to Run of River technology where the kinetic energy of river flow is harnessed to generate electricity. But, unlike Run of River, the In-Stream method can be used to harness electricity both in the river and also from ocean tides. Run of River is used to harness hydel power specifically from streams and river flow. Run of River functions like a small hydropower station that produces electricity based on available hydrological variations of the site within the natural range of the river. Small hydropower plants attract efficient and reliable investments as they take minimum time for construction and exploit the minimum area.

The key steps to building an idea are having a design thinking approach to it. There are five steps involved empathize, define, ideate, prototype, testing, and marketing. Collection of data based on surveys to find the problems faced in a particular field and then proposing design that will aid them in the future. The problem identified here was the lack of a constant supply of electricity in villages. Based on the defined problem the best solution is to build a mini-hydropower plant as most villages have a constant flow of water close by.

The numerous designs of the turbine were made which will be discussed further in the report.

The designs were tested for flaws. The best design with the highest efficiency will be taken into consideration.

Surveys were conducted to get an idea of power requirements in a rural or remote village. The results of the survey showed that most of these villages are built next to a small stream or a river. The survey results also show that the number of appliances in their homes is less and they are small, less power consuming. The research on existing Hydropower plants suggested the construction of a block diagram.

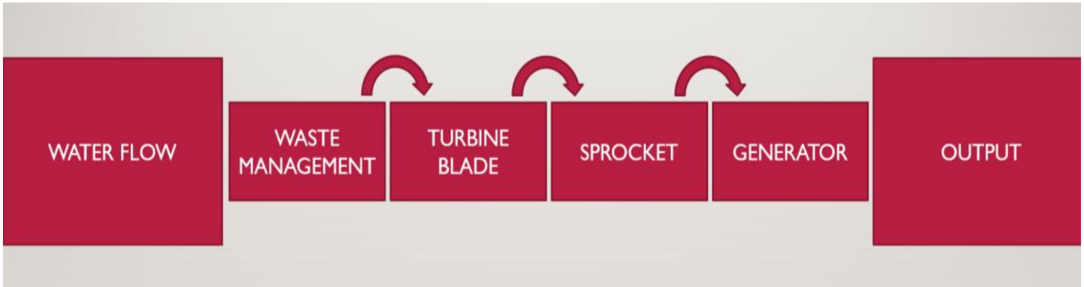

Fig 4: Block diagram

The block diagram of the idea mentioned in this paper is shown in fig 4. As shown in fig 4 the idea can be segregated into four main parts. the input, the processing, the turbine and generator, the output. The input of the turbine is water flowing in a small stream or river which flows next to the village. Based on surveys and research conducted the velocity of the water flow from a stream is around 4-6 m/s. The input of the stream may contain many contaminants such as leaves, plastic bags, rocks, ropes. These impurities can damage the turbine blade. The design mentioned in this paper will contain a mesh attached to the front of the turbine which will not allow impurities to enter the turbine. The mesh is a wireframe with small holes which can be kept either vertical, horizontally, or inclined. The vertical and horizontal mesh design is not preferred because it will not last for a long period. The inclined design, however, will last for a longer period hence that was proposed. The turbine model was designed based on existing models such and the Pelton wheel, Francis turbine. The models were slight modifications of these turbines. The turbine is connected to the axis which is connected to the generator. The generator should have a rating based on the needs of the electricity in the village. The output of the mini-hydro power plant is stored in a battery and supplied to the village for further usage.

III. MATERIALS REQUIRED

To construct a model of the Mini-Hydro power plant we require various materials to make various parts.

- 1 mm thick SS (Stainless Steel) sheet of 120×120 cm² is required to construct the outer cover which holds the turbine blade. The advantage of SS over other metals is it doesn't require continuous maintenance to remove rust, it is flexible and more durable than other materials, it is less harmful to the environment when compared to the use of plastics. All these advantages make this cost-efficient as the maintenance cost is less.
- ABS is used to construct a turbine blade and the mesh for waste processing.
- A cylindrical SS (stainless Steel) rod of 10mm diameter and 20cm length is used for a connecting rod between the turbine blade and generator.
- Ball-bearing to reduce friction.

ABS **(**Acrylonitrile Butadiene Styrene) is an amorphous plastic made out of three monomers such as Acro nitrile, Butadiene, and Styrene. The plastic is opaque and is very hard to break. The strength is what is required for the construction of the turbine blades. ABS with a high concentration of butadiene will have higher strength. The material doesn't corrode to chemicals easily. The advantages of using ABS are that it is waterproof and allows easy rotation of the wheel.

Stainless steel (SS) is very durable when compared to other metals and non-metals when compared to water. The stainless-steel shell on the outer parts of the turbine is meant to be permanent and not removable.

To help the shell to have a long-life SS can be as it has the property of not rusting when exposed to water. The shell cannot be replaced frequently as the Stainless steel is costly.
Various types of equipment are required for the construction of the model such as

- A bending machine
- Sheet metal cutter
- A DC generator of rating
- Wire of required length
- Adhesive materials

Various software's were also used such as:

- AutoCAD was used to make 3D models of the turbine blades and the outer shell casing.
- Ansys was used to calculate the torque produced in the shaft.

CAD model of the particular turbine design is made according to dimension. The weight and the moment of inertia along the axis are calculated using CAD. The inertia and the weight are used for the calculation of the torque of the rotating axis. The model is then constructed using the aluminium sheet for the dimensions of the CAD model. The outer shell model is then made using stainless steel to cover the turbine. The final model after assembling the two parts are tested after connecting the generator to the rotating shaft.
To test the model made the turbine is kept in a flowing stream and the output power from the generator is calculated. Based on the results produced the model will be modified for better performance. The efficiency of the turbine is calculated.
The models were designed according to particular dimensions and were designed for simulation purposes. Four turbine models were constructed based on different ideas related to actual turbine designs.

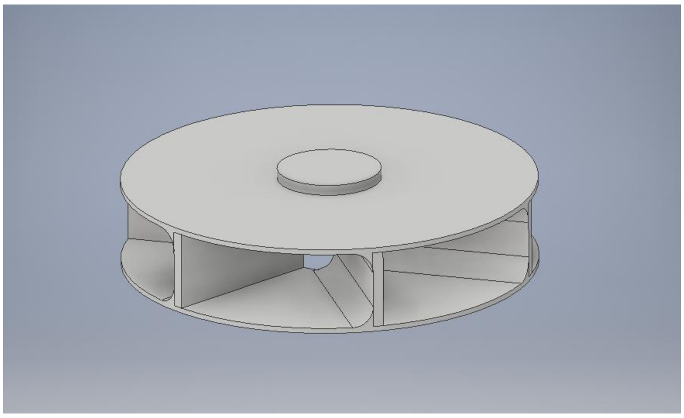

Fig 5: Model 1

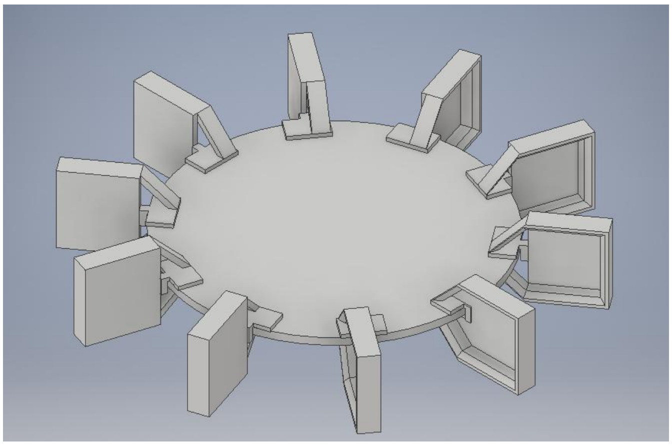

Fig 6: Model 2

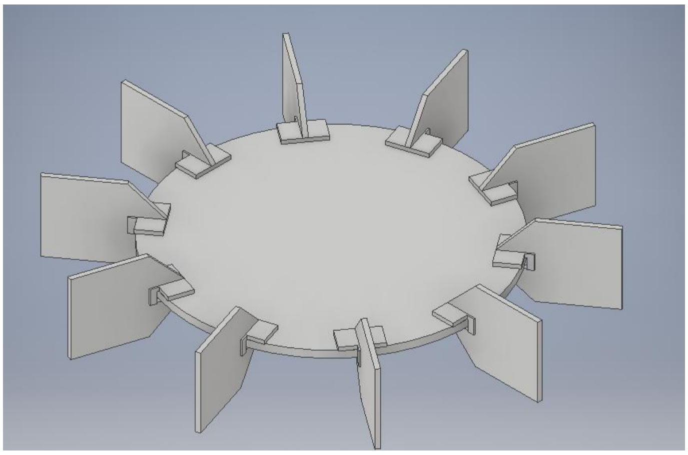

Fig 7: Model 3

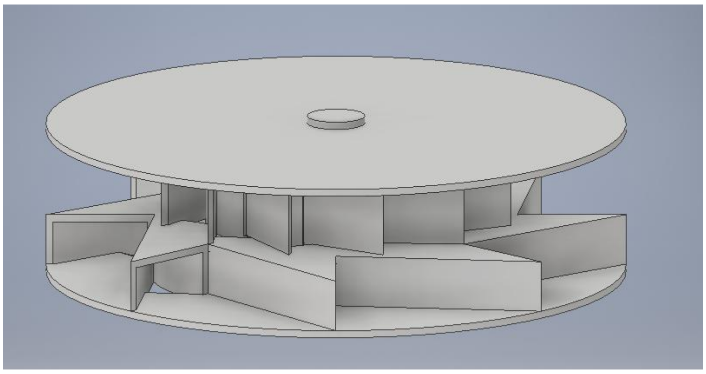

Fig 8: Model 4

The turbine duct has to have two major parts the entry filter to prevent large particles to enter the turbine. The large particles such as stones, leaves, small pieces of clothing can damage the turbine blades by getting them stuck. To prevent such a flaw, a filter-like design was designed as shown in fig 8.

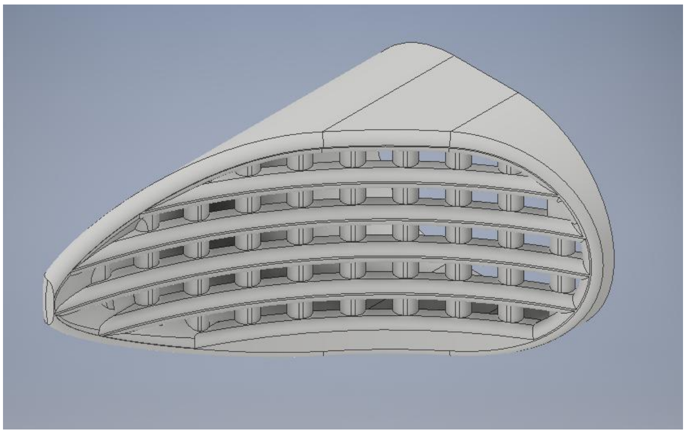

Fig 9: Duct Model Part 1

The rest of the duct contains the part to hold the turbine blade and outlet.

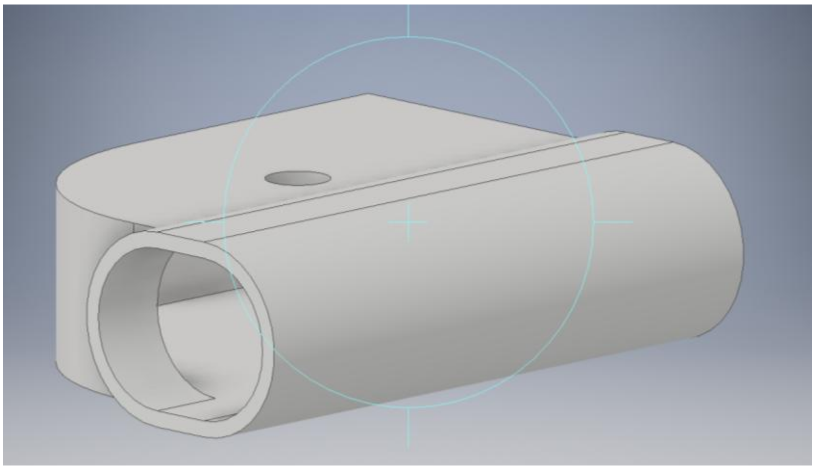

Fig 10: Duct Model Part 2

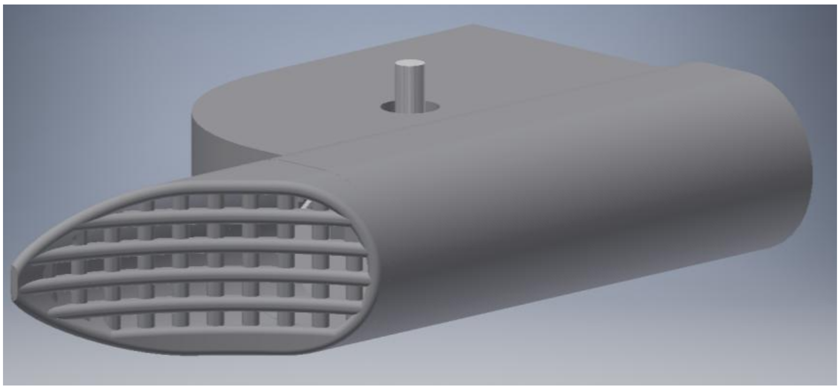

Fig 11: Mini Hydro Power Plant Model

The water is input into the turbine through the mesh to prevent the entry of waste materials such as leaves, plastic bags, and covers, stones. The water without the waste materials will travel towards the turbine blades which will spin due to the tangential force acting on it. The turbine blade is connected to an axis rod which supplies the rotating mechanical energy to a generator of a rating which converts into electrical energy. The electrical energy produced is stored in a battery for further use.

IV. RESULTS

The following analysis was conducted by constraining the turbine models statically on the y-axis and subjecting it to a tangential force of 50 newtons to check the amount of deformation which can be expected after prolonged use. The material chosen for these models was ABS plastic.

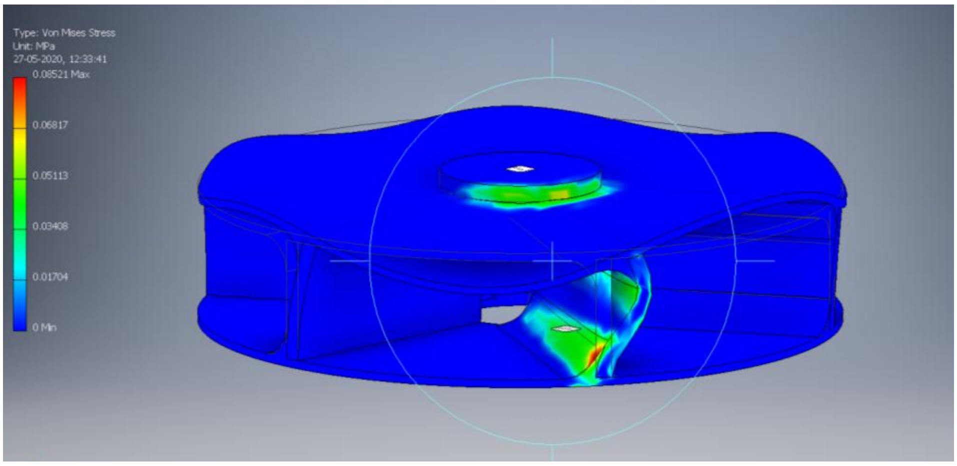

Fig 12: Stress analysis on Model 1

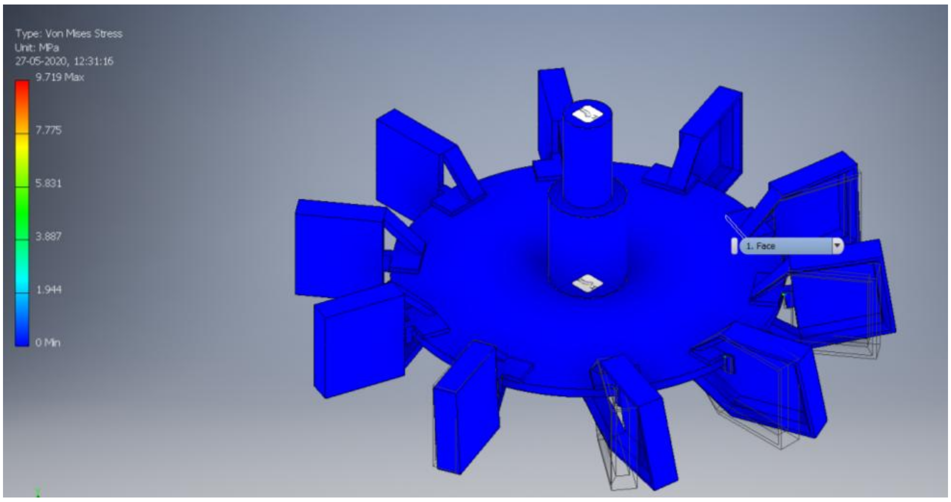

Fig 13: Stress analysis on Model 2

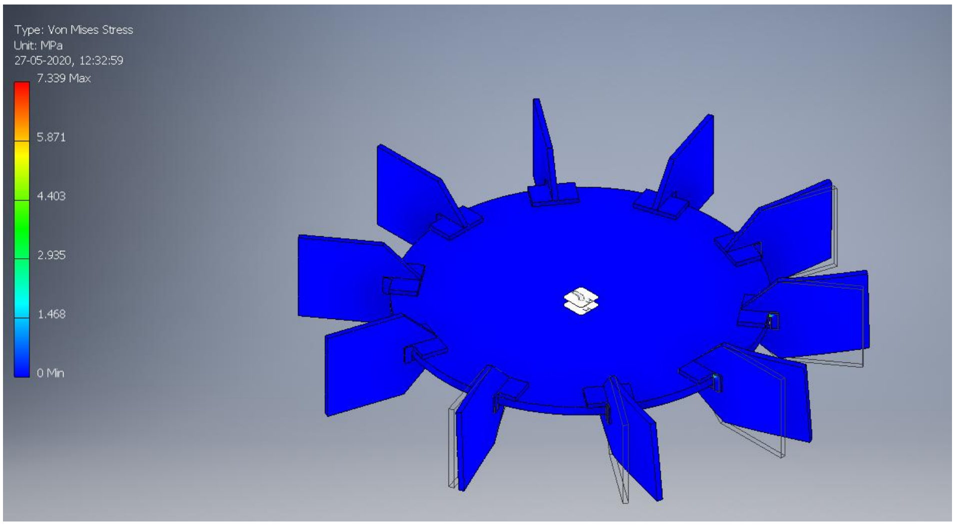

Fig 14: Stress analysis on Model 3

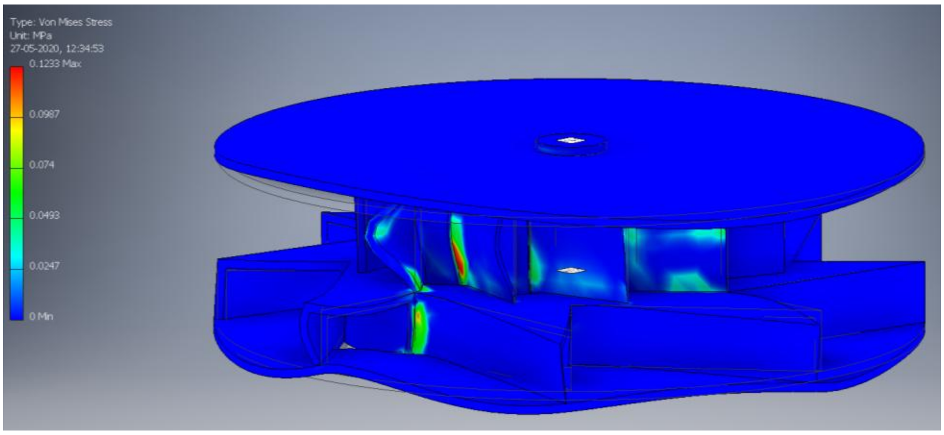

Fig 15: Stress analysis on model 4

The simulation results show a lot of deformation in models 1 and 4 as shown in fig 11 and fig 14 respectively. Models 2 and 3 show the least deformation when compared to the other models as shown in fig 12 and fig 13 respectively.

V. CONCLUSION

Model two has the highest efficiency which has the highest torque hence the lowest rpm. But Model four has the lowest efficiency but it will have the highest rpm, hence it will be more favorable. The stress analysis shows that the best and the most rigid model can be used for prolonged use in model 2. The models were simulated for calculation of torque when subjected to a tangential force and then the results were used to calculate the efficiency. Model two had the highest efficiency and the highest torque the connecting rod when connected to a gear train will produce the highest rpm.

The material used in making the turbine blades ABS plastic. ABS (Acrylonitrile Butadiene Styrene) plastic is a strong plastic with minimalistic side effects when exposed to continuous water flow. The ABS is insoluble in water they usually have coatings that will help in reaction against continuous exposure to light and heat.

Many advancements can be used to make turbines more efficient. A few of them are lubrication, gear train usage, jet input, Using many generators. Lubrication is done to reduce the friction between rotating shafts and the bearings. It can be done by using oil or grease. Lubricating the shafts that connect the turbine blades and the generator will help faster and smoother rotation of the rods hence more electricity can be produced in a short period of time. To cope up with the wet condition, wet grease such as marine greases can be used. Marine grease has the advantage of preventing the rusting of materials and preventing damage to materials from salt. These marine greases have lithium complex thickeners which help them to have the above properties. By connecting gear trains to the shaft connected with the turbine wheel, we can reduce the incoming torque via the shaft. By doing this we get a higher rpm value than before which can be connected to the generator to produce more voltage. Using a gear train helps us to decrease the torque in the shaft which is connected to the turbine blade. Using a high inertia disc attached to the turbine shaft will increase the torque of the shaft but it will also make it hard to rotate the shaft as the shaft will get heavier. Thus, we will get faster rotation without using a disc with the current speed that we get from the rotating turbine blade. By using a jet input onto the turbine blade, we will be able to increase the speed by which it rotates. This works on the basis that the speed at which water strikes the blades of the turbine increases and therefore the rpm increases rapidly. Using multiple generators will help in the production of more electricity.

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S. Sandeep, et. al, "Construction of a Mini-Hydropower Plant." *International Journal of Engineering Science Invention (IJESI)*, Vol. 10(06), 2021, PP 01-09. Journal DOI- 10.35629/6734