Mini Hydel Power Generation From Over Head Tanks Using Pelton Turbine

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Abstract:

The electricity demand is increasing day by day all over the world. A lot of efforts are made to make the buildings productive and self-sustainable. Due to this fact it is proposed to get energy from overhead water tanks. Following this approach, a 20 m high water tank is considered, water in the pipeline rotates a mini-hydro turbine. The purpose of this scheme is to generate power using low cost mini hydro turbine having negligible environmental effects. The experimental setup of this idea consists of a mini-hydro turbine having a diameter of 0.21 m which is coupled with a dc generator via a chain-gear mechanism to obtain desired rotation. The sensor box is designed to monitor the technical parameters. The calculations and theoretical concepts are presented using basic theory and equations of fluid mechanics and turbo-mechanics, outputs are validated using mathematical and experimental results. This system can replace the ordinary backup units for power generation as it will not consume the power of the existing system for charging batteries.

Keywords: *Pelton turbine, Power generation, Green energy, low head, Hydropower.*

1. Introduction

Energy resources of the world are mainly divided into two categories fossil fuels resources and renewable resources. Renewable resources have the advantage of providing free of cost energy without major environmental effect e.g. solar, wind, biomass, and hydro energy, etc. Hydropower represents a great source of producing a handsome amount of energy as compared to fossil fuels [1]. 16.4% generation of the world's power is generated from hydropower plants. Among all the renewable resources the energy of water is more cost-effective. The report of the international journal on hydropower shows that 23% to 63% of countries extracting hydropower for electricity generation [2], [3]. Hydropower plants at a low scale and domestic scale are known as a major resource of renewable energy today. They have more capacity than other renewable resources. Mini-hydel power plants are capable of generating a maximum power up to 5 KW. Mini-hydel power plants are useful in remote areas where a small amount of electricity is required such as for small lightening bulbs, radio or television, etc. This system has low maintenance and installation cost. The mechanism of mini-hydel power plants is the same as dams, the overhead tank acts as a reservoir to store the water and a mini turbine is used to convert the energy of flowing water to rotational energy. The mini hydel power plant is a solution to extract hydropower from an overhead water

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tank to ful fill the power demand at the domestic level. If such plants are installed on overhead tanks than these plants can generate a good amount of electricity along with that it lowers the burden on the distribution network to contribute to the economy of the country. A comparative study is for rural areas using small turbines discussed [4]. Small projects for irrigation discussed in [5]. In previous studies, the specific overhead hydel source is not used for the domestic generation of electricity.

A turbine is a form of machine that converts turning energy from a liquid that is selected through a system of the rotor into operating effort or energy. Rapidly moving fluid (liquids or gases) Strikes the turbine's blades. When the water strikes the runner of the turbine energy of flowing water is transformed into mechanical rotational energy, along with that generator is coupled with the turbine. When the runner rotates the energy produced from the shaft rotation is collected by a generator that converts the rotating mechanical energy to electrical energy. The reaction machine generates the torque by low pressure and weight of water and the impulse machines require high velocity of jet and high pressure to generate the torque. Due to this fact it required casing [6].

The selection of a suitable turbine is very important for setting up a new project. Large scale electrical energy production mostly depends on the uses of turbines. For domestic production, small turbines can be installed which can perform work under low pressure of water. It also has very low maintenance as compared to other large units of the turbine.

2. Methodology

2.1. Hydro Turbine

The hydro turbine is a type of machine that transforms the kinetic energy of the fluid to moving energy. Hydraulic turbine has a row of blades exactly fitted to the rotating shaft. When liquid, mostly water passes through the hydraulic turbine it hits the buckets and makes the shaft rotate. While flowing liquid (water) through the hydraulic turbine the pressure and velocity of the liquid (water) is reduced, the effect of this parameter results in the development of torque and rotation of the turbine give the perfect output.

Hydropower turbines are divided into two main categories; impulse and reaction turbine as in Fig. 1. Each turbine of these types is used for a certain range of values of head and flow rates of water. The reaction turbine is mostly used for those sites having low higher flow and head. A reaction turbine produces power by the combination of pressure and flow of water. In reaction turbine runner is placed directly in the water flowing over the blades rather than striking each individually.

Impulse turbines mostly used because of low flow and high head. The impulse turbine discharges to atmospheric pressure to rotate the runner with the use of the velocity of the water. Flowing of water strikes every bucket on the runner. No section on the lower side of the turbine and the water flows out the bottom. Reaction turbines are mostly used for those sites having higher flow and low head. A reaction turbine produces power by the combination of pressure and flow of water [7].
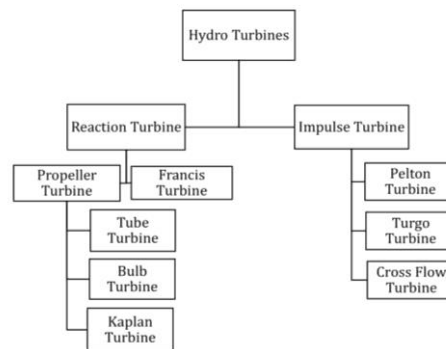

Fig 1: Types of Hydro Turbine

2.2. Turbine Selection

The turbine is directly linked with generator pulleys, gears, and belts. Speed of generator depends on the belt [8][3], the performance of the mini-hydro system

depends on water and the efficiency of turbine wheel pelton turbine is one of the most commonly used impulse turbines. Pelton turbines are suitable in case of high heat. Kinetic energy is only available at the inlet of the turbine. The main parts of the Pelton turbine are nozzle, bucket and runner, casing, and breaking jet. The velocity of the water jet is doubled as compared to buckets and according to the obtained head of water. Fig. 2 shows the structure of Pelton turbine.

Fig 3: DC Generator

2.4. Chain Gears

The dc generator required 452 RPM to give maximum output. The RPM of the turbine was not much enough to reach the requirement of the dc generator. To increase the RPM the gear mechanism is introduced in the system. The chain gear system was introduced to a couple of generators with the turbine. The pulley with more number of teeth was coupled with the turbine shaft and pulley with less number of teeth was coupled with the generator shaft to more RPM at the generator shaft as shown in Fig. 4.

Fig 2: Pelton Turbine

2.3. Generator Selection

Synchronous and induction generators are being used in different types of generation plants and are available in a single and three-phase system [8]. DC generator is used for the establishment of this prototype. DC generator converts mechanical energy into electrical energy. To convert a DC generator into a DC motor no change in construction is required and the same for the motor to the generator, for this reason, we can say that it is a DC machine. So, a self-excited dc generator is a good choice for this system. Fig 3 shows the dc generator used in the experiment.
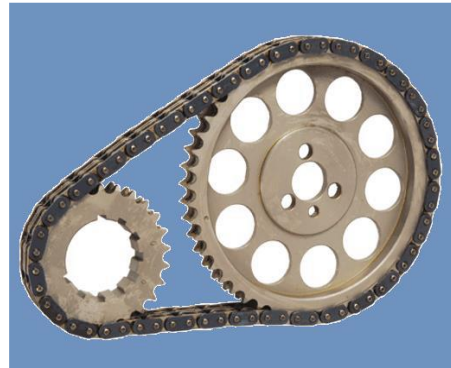

Fig 4: Chain Gears

2.5. Electronic Circuit

2.5.1 Charge Controller:

The charge controller is a circuit which is used for the battery charging purpose. The power generated from the generator is not constant it depends upon the flow of water and the RPM of the turbine. So, to charge the battery from this type of power we need a

charging circuit. Fig. 5 shows the circuit diagram of the charge controller.
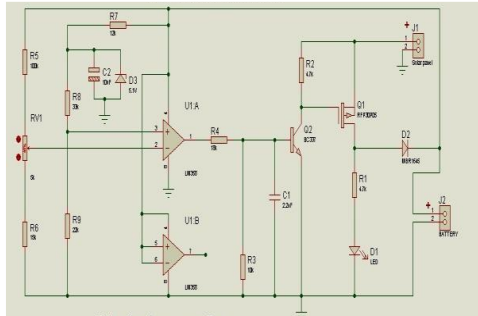

Fig 5: Charge controller

2.5.2 Inverter

The system generated output was useful for only DC devices. The output of the dc generator was not useful for the AC devices. So, to make it useful for all devices an electronics circuit is involved. The inverter is an electronic circuit that converts the DC power into AC power. There are two options in the system both AC and DC now the output of the generator can be used for both types of devices. The inverter circuit involves a number of a transistor for the switching purpose. A step-up transformer is used in the circuit to increase the voltage from 12 V to 220 V which are useful for domestic usage.

2.6 Sensors

There are five sensors used in this prototype for measuring different parameters.

RPM sensor is used to measure the rrotation of the turbine. It is designed with Arduino and LCD is used for the display. Flow sensor is used to measure the flow rate of the water. It installed just before the inlet of the turbine. A vibration sensor is used to measure the vibration of the system. It is installed at the turbine assembly.

A Bourdon tube type pressure gauge is used to monitor the pressure of the water. It installed just before the flow sensor. Water level indicator is used to monitor the level of water. Three LEDs are used to indicate the level of water. It is installed in the water storage tank.

3. Working

The energy of the flowing water through the pipeline is utilized to move the runner of the turbine. The pressure provided to the turbine is very small, due to this impulse turbine will be more suitable hence the Pelton turbine is selected for this design. After entrance from the overhead of the tank into the inlet of the casing, the nozzle is attached to the casing to improve the velocity. High-pressure water than hits the cups followed by exit pipe connected through the tap. A display box depicted in Fig. 6 is used to show the readings of the different parameters (i-e) (flow meter, RPM sensor, Vibration sensor, and Current sensor).

Fig 6: Hardware setup

The working of Pelton turbine Fig. 7 consists of four main parts that are nozzle, buckets and runner, casing, and the last one are breaking jet. The high speed of water flow through the penstock and water jet emerging in the nozzles hit the buckets of the runner. The generator is connected to the shaft of the runner that converts the moving energy into electrical energy and the arrangement of the nozzle is set to the close of penstock which

helps to accelerate water and flow of water with prohibitive speed and greater velocity and eject atmospheric pressure. When the water hits the buckets it divides the bucket into two half and then the turbine starts to rotate. The water jet velocity is double as compared with the velocity of the bucket. The buckets of the turbine are mounted on the circular path with equal spacing. Due to this, the runner rotates at a very high speed. The energy of jet will decrease in the form of kinetic energy because the jet changes its direction due to the spherical shape of buckets and produce U-rotation and waterfall into the tailrace.

Fig 7: Pelton Turbine in the casing

4. Results

A Pelton Turbine was designed by using basic turbine formulae [9]. Complete calculations of all the parameters are depicted in Table I. There is the direct relation between the hydropower, flow of water (Q), Head (H), gravitational force (g) overall efficiency (no) where, H = 20 m;

$$P = Q * H * g * no \qquad (1)$$

Where overall efficiency is directly related to the mechanical efficiency (nm), hydraulic efficiency (nh), and volumetric efficiency (nv).

$$no = nh * nm * nz \qquad (2)$$

The number of buckets is the main part of the designing of the Pelton wheel. The diameter of each bucket is 0.21 m, the total number of buckets is 24. Each bucket mounted together with shaft and used to increase the ability of the turbine to move with good speed and give smooth rotation [10][11][12]. Where C is the coefficient of velocity that varies from 0.97 to 0.99. N is the speed of the turbine in revolution/minute (RPM) which is 800. Specific speed ratio (f) that varies between 0.43 and 0.48. The designed buckets of the Pelton Turbine are depicted in Fig. 8. Table 1 shows the complete parameter calculations of the system.

Table 1: System parameters

S.no	System parameter	Calculations
1	Flow rate (Q)	0.0022 m³/s
2	Velocity of water v_1	19.50 m/s
3	Velocity of cup (u)	8.77 m/s
4	Diameter of turbine	0.21 m
5	Diameter of jet (d)	0.012 m
6	Jet ratio (m)	17.5
7	Number of buckets (z)	24
8	Length of buckets	2.76 cm
9	Breadth of buckets	3.36 cm
10	Depth of buckets	0.72 cm
11	Hydraulic efficiency	0.98
12	Volumetric efficiency	0.9
13	Rotor power	0.3851 KW
14	Mechanical efficiency	0.9
15	Overall efficiency	0.8
16	Power	0.348 KW
17	Specific speed	11.158

Fig 8. Buckets of Pelton Turbine

5. Conclusion

Hydropower is the main natural and clean resource of renewable energy. The best thing about hydropower is that it is free of cost with minimal environmental effects. This prototype used mini hydel technology we can produce free of cost energy which can be stored in the battery. Hydro-power is always being a main and important part of electricity generation. By this mini hydel generation domestic model, we can generate power up to 0.348 kW which can be increased by increasing the flow rate of water. The system can be enhanced and can be used in tall buildings and municipality overhead water tanks. A sensor box is attached which monitors different parameters of the whole system.

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