

# Design and Research of Multifunctional Equipment Based on the Conversion and Utilization of Tap Water Kinetic Energy

Chenkai Liu<sup>†</sup>, Sheng Gao<sup>†</sup>, Junchi Liu<sup>†</sup>, Danyang Li<sup>†</sup>, Bingkun Huang, Yulin Yang, Zihang Zhou<sup>\*</sup>

Century College Of Beijing University of Posts and Telecommunications, Beijing, China, 102101

<sup>\*</sup> Corresponding Author Email: Z2235150997@outlook.com

<sup>†</sup> These authors contributed equally.

**Abstract.** This article constructs a micro hydroelectric power storage device, which mainly consists of a micro water turbine unit, a voltage regulator, and a power storage unit. The micro water turbine unit is located inside the municipal water supply pipeline and uses the hydrodynamic force flowing in the pipeline to drive power generation. The generated electrical energy is first transmitted to the voltage regulator for stable processing, and then transmitted to the energy storage unit for storage, ultimately achieving the process of converting the water flow energy in the tap water pipeline into electrical energy. This product innovatively proposes to improve the traditional open water bucket turbine into a miniature closed water bucket impact turbine. Secondly, the product transforms large hydroelectric power plants into micro applications for embedded high-pressure water flow impact turbines in pipelines. Finally, this study innovatively investigates the feasibility of using micro bucket turbines for power generation in high-pressure water pipes, providing reference for the future development of residual pressure power generation technology.

**Keywords:** Hydroelectric Power Generation, Energy Conversion, Energy Conservation and Emission Reduction.

## 1. Introduction

In recent years, with the gradual deepening of the concept of energy conservation and emission reduction, the environmental awareness of Chinese citizens has also gradually increased [1]. According to the latest population census data in Beijing, the current population has reached 219 million, accounting for 1.55% of the national population. Compared with 2010, there has been an increase of 2.281 million people in the past decade, which means that the resources needed by Beijing are increasing exponentially [2]. According to existing data, the annual natural gas consumption in Beijing needs to reach 100 billion cubic meters, while the daily consumption of gasoline and diesel is about 20000 tons, equivalent to four and a half times the volume of Kunming Lake throughout the year [3]. At the same time, the annual consumption of aviation kerosene is 4.7 million tons, and during the winter heating season, the daily coal consumption can reach a peak of 100000 tons [4]. Faced with such massive energy consumption, it is imperative for Beijing to carry out energy-saving and emission reduction actions.

In this context, in response to the call for reducing energy consumption and pollution emissions, this article firmly believes that hydropower, as an economical and clean renewable energy source, has been developed and created globally, although it is still relatively rare in the field of individual household self flowing power generation [5]. Based on this, this article develops a micro hydroelectric power generation and energy storage system based on the daily water supply network [6]. The system uses the residual power of the water flow in the household water pipe to impulse a micro water turbine, converting the power and position energy of the flowing water into the mechanical energy of the water turbine, and thereby driving the generator to generate electricity. This accumulated electricity is sufficient to supply micro electronic devices related to water resource maintenance operations, which have a lower demand for energy. Meanwhile, according to research calculations, the product can generate 0.046KW \* h of electricity when working for 24 hours a day. Assuming that there are 1.5 million households in Beijing installed and used, which is 15% of households installed, the annual

electricity generated is  $50370000\text{KW} \cdot \text{h}$ , which can supply the lighting system in Beijing for 1027 days.

## 2. Design scheme of micro hydro power generation system

The product in this article is mainly built on micro hydro power generation devices, voltage stability units, and energy storage units. A micro water turbine placed inside the municipal water supply pipeline utilizes the flowing hydraulic power in the pipeline for power generation operations. The current generated by the micro water turbine is input through the connected voltage regulation module, and the stable current output by this module is then transmitted to the energy storage module. The three together form the energy storage part of the entire micro hydropower generation system. The accumulated electricity is sufficient to supply low-power end devices in water resource management systems, such as LED light strips, small portable chargers, smart water meters, and induction faucets. If this device is widely promoted, it will save electricity expenses for household users and extend the service life of electrical products. It facilitates the daily lives of the people, greatly reduces electricity consumption for our country, thereby reducing carbon emissions and mitigating the development trend of global warming, as shown in Fig 1.

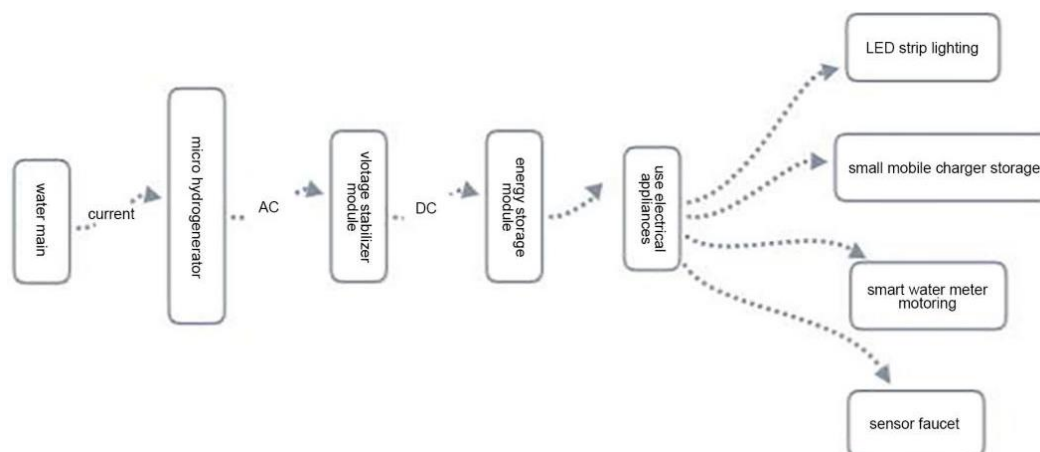


**Figure 1.** Schematic diagram of energy conversion device principle

### 2.1. Working principle of micro hydro power generation system

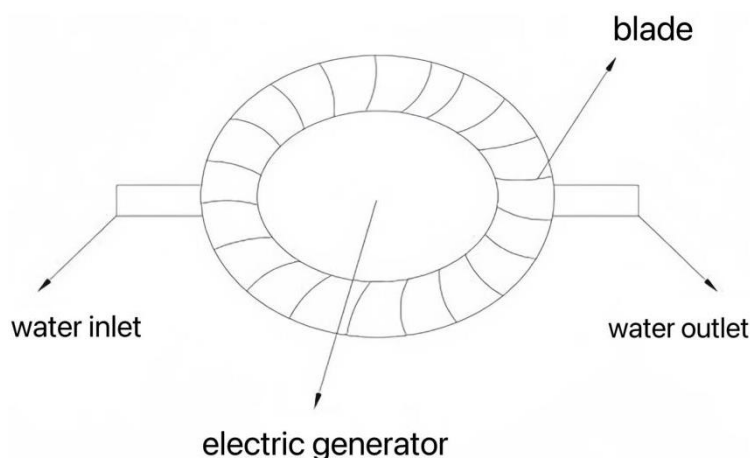


**Figure 2.** Schematic diagram of micro hydro generator impeller

According to statistical analysis, the water pressure in China's household water supply system usually ranges from 0.05 to 0.35MPa, which is sufficient to drive the impeller shown in Fig 2 to rotate. The micro hydraulic power generation device operates in an electromagnetic induction manner, mainly consisting of two components: a micro water turbine and a generator. By activating the blades of the micro hydraulic module through the flow of water in the pipeline, the magnetic rotor rotates in

the magnetic field to generate electricity [7]. This device converts the momentum of tap water into the mechanical energy of a water wheel and further drives the generator to rotate to generate electrical energy. According to the experimental data shown in Fig 3, the micro hydroelectric generator can generate a voltage between 2.0V and 18.8V under standard operating conditions.

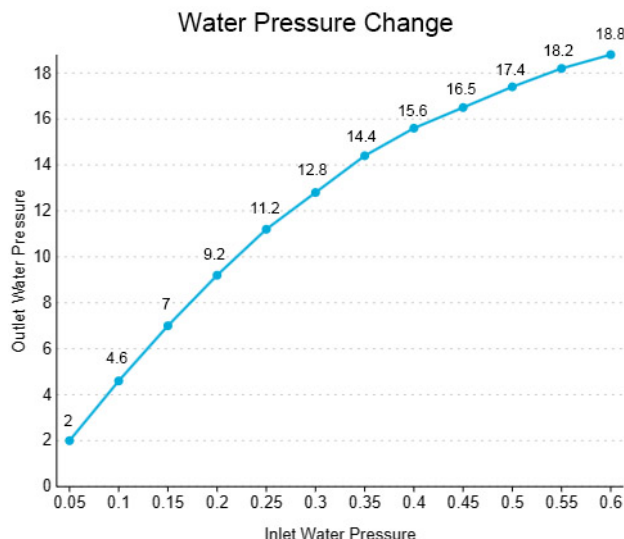


**Figure 3.** Relationship between Generator Output Voltage and Water Pressure

#### (1) Mechanical part

As shown in Fig 4 and Fig 5, the main components of this device include a water barrier shell, framework, magnetic pole rotor, wiring post, coil, shaft, impeller, impeller magnet, cooling fan, inlet pipe, outlet pipe, etc.

The main body of the device is divided into two parts. The first part is the impeller and inlet and outlet water pipe device, and the second part is the hydroelectric generator, which is composed of a magnetic pole rotor and a surrounding coil inside. Both parts are wrapped in a waterproof shell, which can prevent water from entering the rotor from the motor shaft, causing increased resistance to rotor rotation, as well as noise or jamming of the motor due to impurities in the water entering [8]. At the same time, in order to prevent the generator from being used for a long time or in high-temperature and high-pressure environments, due to the inability to dissipate heat, the internal temperature of the motor will increase, the generator shaft will wear faster, the material will deform, and the service life of the generator will be affected. We have installed cooling fan blades at the top and bottom of the generator magnet to cool and dissipate heat while the generator rotates at high speed.

The water flows out of the inlet pipe 1, pushing the impeller of the small water wheel to rotate, and then the magnetic pole rotor rotates accordingly, cutting the magnetic field line and generating electricity in this way. In other words, it is to use a micro water turbine device to convert the flow power of tap water into mechanical work of the water turbine, and this torque continues to act on the generator set, ultimately converting it into electrical energy.

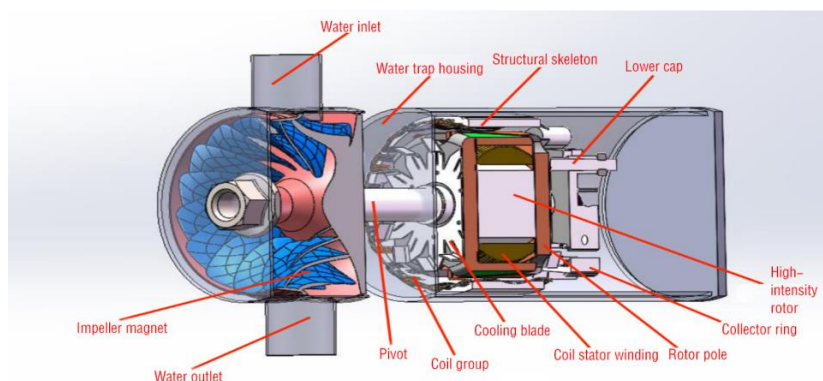


**Figure 4.** Section view of hydroelectric generator

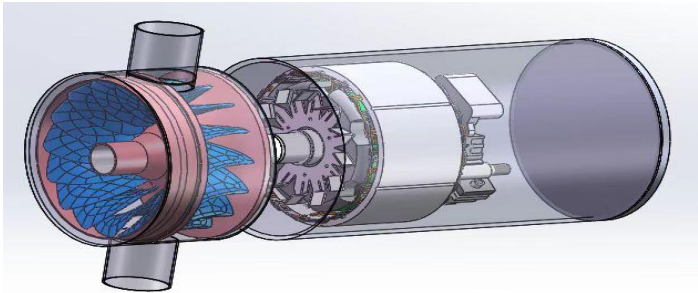


Figure 5. Axonometric diagram of hydroelectric generator

3. Circuit section - Voltage stabilizing module

3.1. Rectifier circuit

The voltage regulation module is equipped with a set of full bridge rectifiers, as shown in Fig 6. Its core function is to convert the alternating current generated by small water turbines into continuous DC power supply. This circuit is constructed on four single conductive diodes, which transform AC energy into a fluctuation form of DC electricity through the unique single line flow characteristics of the diodes. Then, the DC wave motion is made to have a relatively stable waveform through filtering capacitors C1 and C2.

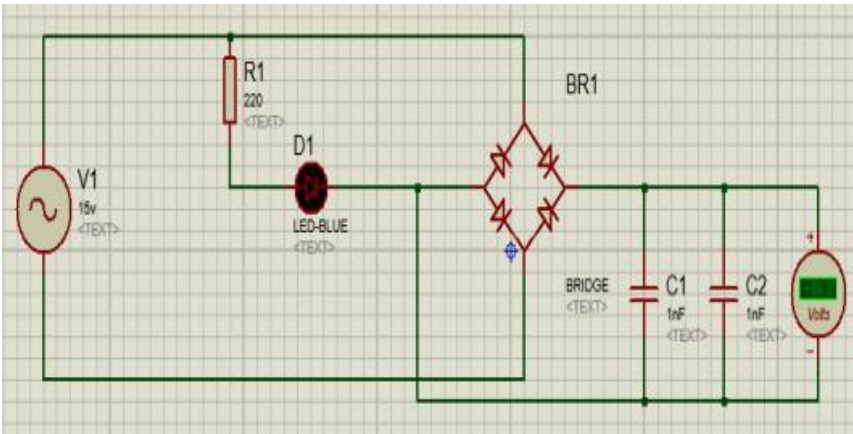


Figure 6. Voltage stabilizing circuit

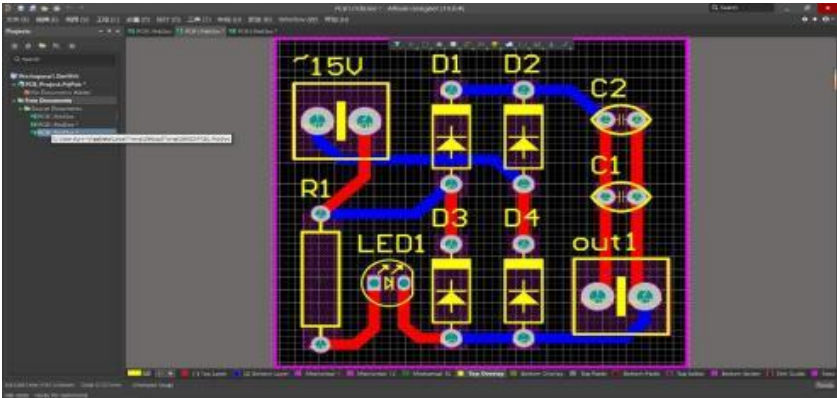


Figure 7. PCB circuit diagram of voltage regulator module

The voltage input range is 4V to 40V, with a peak output voltage of 60V and a stable oscillation frequency of 100KHZ. The NPN type transistor switch has a voltage resistance of 65V and a nominal current of 5A. By manipulating the switch pins of LM2587-ADJ to enter conductive and non-conductive modes, the charging and discharging process of inductor L1 can be regulated.

By manipulating the on/off ratio of switch pins, the output voltage can be adjusted; By adjusting the ratio of resistance R1 to R2 in the feedback circuit, the duty cycle can be changed. The output voltage UOUT of the circuit can be calculated using the following formula:

$$U_{OUT} = V_{REF} (1 + R_1 / R_2) \quad (1)$$

The reference voltage VREF in this scheme is set to 1.23V. After fine adjustment of the variable resistor R1, the ratio of R1 to R2 is 3.06, thereby achieving stable output voltage VOUT at 5V [9].

### 3.2. Energy storage module

According to Fig 7, the energy storage unit consists of a power management component and a lithium battery. At present, there are numerous power management integrated circuits on the market, but considering stability and cost-effectiveness, TP4056 has been selected as the power management module after comprehensive consideration in this design. This circuit uses built-in power type transistors to charge lithium batteries with continuous current and constant voltage, and its input power supply voltage has a wide range of applications.

After receiving a high-level signal at the CE enable port, the power management unit will start the lithium battery charging program [10]. If the voltage value of the lithium battery is less than 3V, the power management unit will charge it initially with a lower current; Once the voltage of the lithium battery exceeds 3V, it will switch to fixed current mode to charge the lithium battery. In this mode, the value of the charging current can be determined by adjusting the resistance R4, and this value can be obtained through specific calculation methods.

$$R = \frac{1200}{I_a} \quad (2)$$

The charging current of the lithium battery in this design is set to 1000MA. According to the formula, its charging capacity is sufficient to supply the required power for low-power end devices in the water resource operation and maintenance system, such as bright LED light strips, mini portable chargers for storing electricity, as well as intelligent meter reading devices, data collectors, induction faucets and other facilities. Looking at the overall situation, this equipment is exquisitely designed and has moderate economic investment. Although it is slightly limited in operation, it can greatly simplify cable layout in small-scale power systems and reduce the maintenance costs required for smart buildings; The innovative hydraulic energy converter has improved efficiency, not only occupying less space, achieving clear and visible energy-saving and environmental protection, but also effectively alleviating the splashing problem caused by excessive water flow power, promoting energy conservation and reducing emissions, and has broad market potential. This device can also reduce electricity usage and correspondingly reduce carbon emissions, helping to alleviate the global greenhouse effect problem, as shown in Fig 8-10.

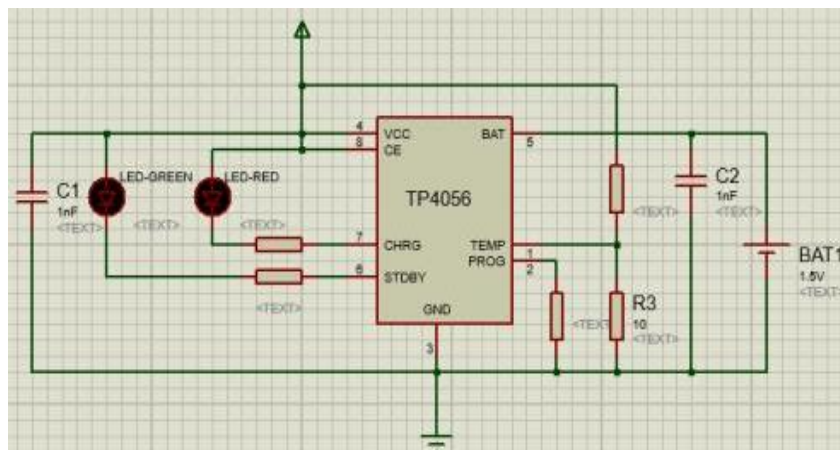


Figure 8. Power management module circuit

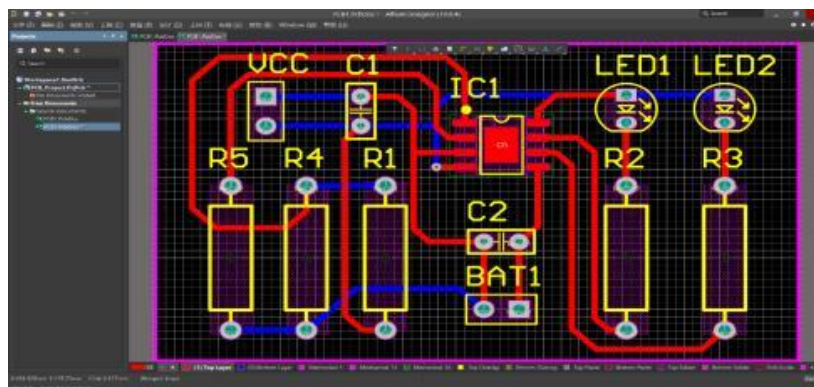


**Figure 9.** Power management module PCB circuit diagram

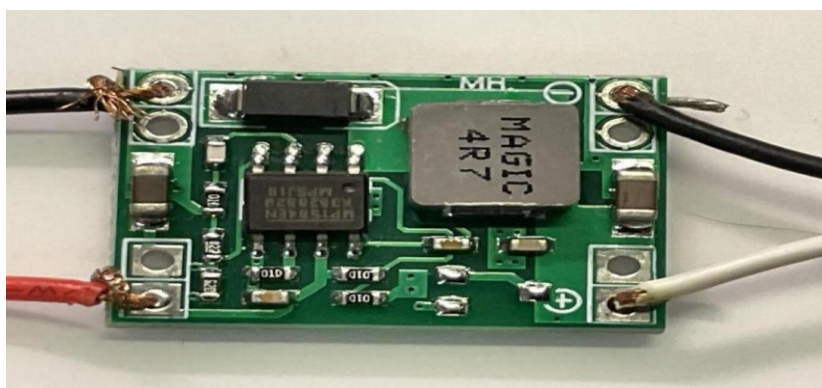


**Figure 10.** Voltage stabilizing circuit module

#### 4. Working principle and performance analysis

This design is built on miniature hydroelectric power generation units, voltage adjustment devices, and energy storage units. The miniature water turbine power generation unit set up in the pipeline supply system drives the rotation of the water turbine through flowing water in the pipeline, thereby driving the magnetic pole rotor to bypass the magnetic field and generate current, realizing the conversion of the power and potential of tap water into the mechanical kinetic energy of the water turbine, and converting this mechanical energy into electrical energy. The micro generator is connected to the receiving port of the voltage regulating device through its output port, which then transmits the stable voltage to the energy storage unit. These components jointly construct the micro hydropower generation and energy storage module of this design. The saved electricity can provide low power consumption equipment in water resource management systems, including LED light bars, portable power banks, intelligent meter reading devices, and automatic sensing faucets.

According to the experimental results designed for this device, when the hydrodynamic pressure is within the range of 0.05WPa to 0.6WPa, the DC rectifier can output a voltage of 1.2V to 17.6V, and its power generation ranges from 3W to 12W. After processing with a full wave bridge rectifier and LM2587-ADJ regulated voltage stabilizing circuit, the device can provide a constant 5 volt DC input voltage for lithium-ion batteries. In addition, when charging lithium-ion batteries through the power management unit, the average charging current can reach 890 milliamperes.

#### 5. Conclusion

This article uses the water flow dynamics in the self flowing pipeline and the micro water turbine to initiate the power generation operation, which can efficiently convert the residual water head in the water pipe into electrical resources. This approach is in line with China's energy-saving and emission reduction policy orientation, and has a positive impact on environmental protection and energy conservation. Due to the fluctuation of water pressure and flow speed in municipal water

supply, the power generation performance cannot be maintained constant. Therefore, the product is equipped with an electric power management unit that has a low voltage pre charging function to ensure a safe and efficient charging process for lithium batteries. The new water kinetic energy conversion equipment can improve work efficiency, occupy less space, and has distinct energy-saving and environmental advantages. It can also solve the problem of excessive water pressure splashing, thus ensuring a safe and efficient charging process for lithium batteries. To achieve energy conservation and consumption reduction, this product can provide the required energy to low-power terminal devices such as smart water meters, data collectors, and automatic sensing faucets. This product is designed with simplicity and economic cost, significantly reducing wiring requirements in small-scale power consumption power supply networks, reducing daily operating expenses of intelligent buildings, and demonstrating huge application potential in the market with its significant energy-saving and environmental protection characteristics. Based on the above analysis, the tap water kinetic energy conversion equipment can provide electricity in real-time, and its supporting transmission line construction is not complex. This system has a series of significant energy-saving and emission reduction characteristics, such as low-cost construction, long-term stable operation, firm structure, high cost-effectiveness, low maintenance costs, convenient operation, and no environmental pollution.

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