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Application of Alternating Current (AC) Generators in Turbine Systems for Sustainable Lighting Solutions in Rice Fields Near Beron Reservoir

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Abstract: *Beron Reservoir, located near rice fields, channels water into the surrounding agricultural lands. The water flow from this reservoir has the potential to be utilized for providing lighting to rice fields at night, optimizing the photosynthesis process for rice plants. The river flow rate, measured at approximately 1.9 m/s, is considered relatively low, making it challenging to generate large-scale electrical energy. This scientific study explores the application of generators in turbine systems to harness the water flow from the reservoir. Data was collected through direct observation and secondary references, acknowledging the potential risks of failure during the development process. The experimental results showed a 2:1 loss ratio in the generator's operation. The average output voltage produced was 2.19V. Testing conducted at five different times over a single day confirmed that the generator system could be applied for the intended purpose.*

Keyword: *application, generator, turbine*

Introduction

The Beron Reservoir, located in Sumberejo Village, Tuban Regency, serves as a critical resource for the surrounding community. Adjacent to the reservoir lies an extensive rice field, which serves as the primary source of income for many local residents. Water flowing from the reservoir into these rice fields presents an opportunity to provide lighting during nighttime hours. Visible light, with a spectrum range of approximately 400 nm to 700 nm, is essential for the photosynthesis process in plants [1]. While the highest rate of photosynthesis typically occurs between 11 a.m. and 2 p.m., this rate can be significantly reduced under cloud cover. To ensure that the photosynthesis process remains uninterrupted, artificial lighting provided by electric lamps that operate continuously is required [2].

An Alternating Current (AC) generator is an ideal solution for this purpose, particularly when integrated with water turbines[3]. The generator selected for this application must be cost-effective, simple to construct, and easy to maintain. The AC output from the generator is converted into Direct Current (DC) using a rectifier, which then channels the electricity through a capacitor and subsequently powers the lighting system. This system offers a practical and sustainable approach to supporting agricultural productivity while addressing the energy needs of the local community.

Methodology

1. Water Turbine

Water turbines are essential components in hydropower systems, designed to harness the potential energy of water and convert it into mechanical energy[4]. This mechanical energy is subsequently transformed into electrical energy through the operation of a generator. The process begins with the thrust of the water current, which drives the turbine blades into motion[5]. This rotation, directly linked to the generator, enables the production of electricity that powers homes, industries, and various facilities.

Turbines are categorized into two main types based on their operational principles: reaction turbines and impulse turbines. Each type is specifically suited to certain conditions and applications, making it important to understand their unique characteristics[6].

The first type, the reaction turbine, is the most commonly used. It operates based on the principle of pressure difference. When water flows through the rotating component of the turbine, known as the runner, it experiences a drop in pressure both at the regulating angle and on the runner itself. This pressure difference generates the force needed to rotate the runner[7]. Reaction turbines are particularly effective in environments where water pressure varies. Examples of this type include propeller turbines and Kaplan turbines. Propeller turbines are simple in design and are typically used in low-head applications where a large volume of water is available. Kaplan turbines, on the other hand, feature adjustable blades that allow them to perform efficiently even under varying flow conditions[8].

The second type, the impulse turbine, operates on a different principle. It converts the potential energy of water into kinetic energy before the water interacts with the turbine blades[9]. This transformation occurs within nozzles, where water is directed at high pressure to produce a high-speed jet. When this jet strikes the blades of the turbine, it causes a change in flow velocity and momentum. This change creates an impulse that drives the rotation of the turbine. Impulse turbines are particularly well-suited to high-head, low-flow scenarios. One prominent example of an impulse turbine is the Pelton turbine, which is designed with a series of buckets attached to a wheel[10]. The water jet strikes these buckets, transferring energy and setting the turbine into motion. Pelton turbines are known for their efficiency in high-head applications.

In summary, reaction turbines and impulse turbines each have distinct methods of operation that make them suitable for specific types of hydropower conditions. Reaction turbines excel in low to medium head scenarios where pressure variations are significant, while impulse turbines are ideal for high-head environments that maximize water’s kinetic energy. Understanding the differences between these two types is crucial for selecting the appropriate turbine to ensure efficient energy conversion in hydropower plants.

2. AC generator

AC generators, also known as alternators, alternating current (AC) generators, or synchronous generators, are a type of synchronous machine that converts mechanical energy into electrical energy in the form of alternating current[11]. These machines are fundamental in electricity generation, used in power plants, renewable energy systems, and various industrial applications. The operation of an AC generator is based on Faraday's law of electromagnetic induction, which describes how a changing magnetic field can induce an electromotive force (emf) in a conductor.

In an AC generator, the rotor is mechanically rotated within a magnetic field, which causes the magnetic lines of force to change relative to the coil of wire (also called a solenoid)[12]. The generator typically consists of several key components: a stator (the stationary part that houses the coil of wire), a rotor (the rotating part that moves within the magnetic field), a fixed magnet or electromagnet that creates the magnetic field, a sliding ring (called a slip ring), and brushes that maintain an electrical connection to the external circuit[13].

When the rotor turns, the coil moves through the magnetic field, which causes the magnetic lines of force to cut across the conductor of the coil. According to Faraday's law, this motion induces an emf (electromotive force) in the coil[14]. The alternating motion of the rotor causes the polarity of the induced emf to reverse periodically, generating alternating current (AC) electricity. As the rotor continues to spin, the current alternates in direction, producing a sinusoidal waveform of AC power.

The slip rings and brushes are used to maintain the electrical connection between the rotating coil and the external circuit[15]. The slip ring allows the coil to rotate continuously without losing contact, ensuring a steady flow of induced current. The brushes press against the slip ring to transfer the induced current to an external load, such as a grid or an electrical appliance.

The number of rotations of the rotor is synchronized with the frequency of the AC current generated. This frequency is determined by the number of poles in the stator and the rotational speed of the rotor[16]. For instance, in a typical 60 Hz generator, the rotor must rotate at a speed that corresponds to 60 cycles per second, ensuring that the induced current alternates direction 60 times each second.

Overall, the AC generator is an essential device in converting mechanical energy into electrical energy through the interaction of magnetic fields and conductors, based on the principles of electromagnetic induction. This principle, first demonstrated by Michael Faraday in the 19th century, is the foundation of many modern electrical machines, including transformers, electric motors, and generators.

3. Uncontrolled rectifier 1 phase half wave

A single-phase rectifier circuit is designed to convert alternating current (AC) to direct current (DC)[17]. In a single-phase half-wave uncontrolled rectifier, only one diode is used to rectify the input AC signal, making it one of the simplest types of rectifier circuits. This rectifier is commonly used in applications where the current requirements are low, and the rectification does not need to be highly efficient.

The main components of a single-phase half-wave rectifier circuit include:

- AC Input Source
  A single-phase AC voltage supply.

- Diode
  The key component that allows current to flow only in one direction, thus rectifying the AC signal.

- Filter Capacitor
  A component used to smooth the DC output by filtering out ripples.

The operation of the half-wave rectifier is based on the diode's unidirectional conduction property. Here's how it works:

- Positive Half-Cycle
  When the AC input voltage is in its positive half-cycle, the anode of the diode is at a higher potential than the cathode. This makes the diode forward biased, allowing current to flow through the diode and into the load. During this period, the diode is ON, and the output voltage follows the AC input (except that it's rectified to allow current in only one direction).

- Negative Half-Cycle
  When the AC input voltage is in its negative half-cycle, the anode of the diode is at a lower potential than the cathode, causing the diode to become reverse biased. A reverse-biased diode blocks the current flow, and as a result, no current flows through the load during this period. The diode is OFF, and the output voltage is zero or very close to zero.

This process repeats continuously, resulting in a pulsating DC output where current flows only during the positive half of the AC cycle. The output is not pure DC and still contains ripples, which can be smoothened out by adding a capacitor across the load.

4. Capacitor

Capacitors play a crucial role in smoothing out the output of rectifier circuits, particularly in power supplies that convert AC to DC. When combined with rectifier diodes, capacitors help refine the shape of the output signal, transforming it from a pulsating DC waveform into one that is closer to a steady DC voltage.

In a rectifier circuit, especially a bridge rectifier, diodes convert the alternating current (AC) from the step-down transformer into a pulsating DC signal[18]. This DC signal, however, is far from a smooth, continuous line; it still has significant ripples or fluctuations, which can be undesirable for many electronic applications. This is where capacitors come in.

Capacitors store electrical energy in an electric field by accumulating an imbalance of electric charge on their plates. The ability to store and release energy allows them to smooth out voltage fluctuations in rectified signals.

Working of a Capacitor in a Bridge Rectifier Circuit

- Charging Phase
  As the rectified voltage rises during each positive half-cycle of the AC input, the capacitor begins to charge up. The voltage across the capacitor increases as it accumulates charge, following the input voltage rise but at a slower rate.

- Discharging Phase
  When the rectified voltage starts to fall (during the negative half-cycle or when the rectifier switches off), the capacitor discharges its stored energy. The discharge occurs through the load,

helping to maintain a more constant voltage even as the input voltage drops.

- Repeat Cycle

This process of charging and discharging repeats continuously for each cycle of the rectified waveform. The capacitor continuously compensates for voltage dips and smoothens out the peaks, reducing the amplitude of the ripples and making the output closer to a straight line, or a smoother DC voltage.

5. Lamp

The lamp used is an LED plant grow lamp because it is very appropriate to increase plant production [19]. The lights will be turned on starting in the late afternoon so that the rice plants get a supply of light for photosynthesis. Rice plants will be more productive if the photosynthesis process is assisted by lights at night. However, in order to grow healthily, plants should be irradiated by the sun or LED lights with a total time not exceeding 14-16 hours per day [20].

6. Method

This research begins with the first step of defining the problem to be solved or the research objectives to be achieved. In the context of electrical systems such as AC generators, the problem could range from improving the efficiency of converting mechanical energy into electrical energy to analyzing design parameters that affect the generator's performance. Once the problem is defined, the next step is to develop a theory that underpins the understanding of how the generator operates. This theory involves relevant physical principles such as Faraday's Law of Induction, which explains how changes in the magnetic field can induce electromotive force (emf) in the stator coil. The theory will also cover the relationships between various design parameters, such as magnet strength, the number of turns in the stator, and the distance between the rotor and stator, all of which impact the efficiency and power output of the generator.

Once the theory is developed, the next step is to search for references that can support the understanding and provide relevant data for the research. References from scientific journals and related literature will provide information on similar experiments, empirical data, and methodologies used by other researchers, which can be compared with the system under investigation. Some of the key parameters to be determined in this research include the type of magnet used, the number of turns in the stator, the stator diameter, and the distance between the rotor and stator. Using the data from the available references, calculations of various electrical quantities, such as induced voltage, power output, and generator efficiency, can be made.

Results and Discussions

The level of losses in the application of a generator with taiming gear can be seen in the following test table.

Table 1. No-Load test result

No	Time (O,clock)	River Flow Speed (m/s)	Savonius Generator and Turbine Application Losses (rpm)
1	6	0,84	27
2	9	1,13	43

3	12	2,52	44
4	15	3,01	60
5	17	2,38	43

From the table data above, it can be concluded that the average speed of the river flow is 1.97 m/s with an average application loss rate of 43 rpm.

Table 2. test result

No	Time (o'clock)	River Flow Speed (m/s)	No-load turbine rotation output (rpm)	Loss rate (rpm)	Voltage (V)
1	6	0,84	50	25	0,94
2	9	1,13	54	27	1,08
3	12	2,52	85	42	2,88
4	15	3,01	88	44	3,42
5	17	2,38	81	40	2,67
Ave	1,97	71	27	2,19	

The results of the test conducted over five different times reveal that the flow rate of the river shows significant variation. This is an important factor to consider when applying the river’s flow to power a generator. As the flow rate changes, it impacts the efficiency and performance of the generator, especially when using the timing gear method, which is commonly employed to regulate the speed of the turbine and generator. The fluctuations in river flow speed mean that the generator’s output is not constant and will naturally decrease during periods of lower flow. This variability underscores the importance of understanding the relationship between the river’s flow rate and the generator's operational capacity.

From the data collected, it is clear that the output voltage generated by the system is highly dependent on two factors: the speed of the river flow and the gear ratio between the turbine and the generator. These two factors work together to determine the performance of the generator. The gear ratio plays a crucial role in translating the kinetic energy of the river’s flow into mechanical energy, which is then converted into electrical energy. A proper balance between the flow rate and the gear ratio is essential to ensure that the generator operates at optimal efficiency. In this case, an average river flow speed of 3.01 m/s was found to be the most effective, yielding a stable output under the given conditions.
The average voltage generated by the system, when measured under conditions with no load, was found to be 2.19V at 88 RPM. This data provides insight into the generator's performance under typical conditions, revealing that the generator can produce a moderate voltage with relatively low RPM under the river's average flow rate. However, these results also highlight the limitations of the system, particularly in terms of voltage output, which is directly influenced by the variable nature of the river's flow and the applied gear ratio. In conclusion, it can be inferred that the efficiency of the generator is closely linked to the stability of the river’s flow speed and the precise calibration of the gear mechanism, both of which are crucial for maximizing output voltage and ensuring reliable power generation.

Conclusion

1. The output voltage of the generator is significantly influenced by the magnetic flux density generated by the permanent magnet and the number of turns in the stator coil.
2. The design of the generator is determined by optimizing the number of stator poles to achieve the desired voltage output.
3. The performance of the generator is directly affected by the flux density

produced by the permanent magnet and the number of stator coil turns, emphasizing the importance of these design parameters in enhancing efficiency.

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