Academic Journal of Engineering and Technology Science
ISSN 2616-5767 Vol. 2, Issue 1: 199-209, DOI: 10.25236/AJETS.020033

Design of uphill transmission system based on optical storage and power supply

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Abstract: *There are a large number of mountain cities in our country where exist many roads with many slopes of large gradient, it is time-consuming and laborious to carry out bicycles and other related activities. In order to solve this problem, this paper studies and designs a solar powered auxiliary slope climbing system combined with bicycle, which will make up for its difficult climbing. The solar-powered uphill auxiliary system is composed and operated as follows: the solar panel installed on top of the bus station near the ramp is used for the power supply, the DC motor is started by the pressure sensor on the pedal, the pedal is pulled by the connected cable and rises steadily through the special structure with the guide rail. Finally, the feasibility and effectiveness of the system are verified by simulation experiments of key circuits.*

Keywords: *climbing, photovoltaic power supply, motor traction, pressure induction.*

1. Introduction

With the gradual depletion of fossil energy, the development and use of solar energy technology have become an important part of the sustainable development strategies of countries around the world [1]. In the current development of renewable energy, the application of solar technology has become the fastest and most stable. It is expected that the development rate of renewable energy will continue to increase in the 22nd century [2], The extensive use of solar energy technology can effectively reduce environmental pollution, reflecting

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the concept of green environmental protection and the combination of nature and technology.[3]In the outdoor, due to the influence of the weather cannot ensure adequate light, coupled with dust cover to reduce the efficiency of power generation [4-5]. A year after installation in the united Arab emirates, for example, photovoltaic power was reduced by nearly 70%. It was found that dust concentration or high wind speed would seriously affect the power generation efficiency [6-7]. Therefore, a kind of controller was proposed to optimize the power supply strategy and effectively improve the energy utilization efficiency [8-13].

Nowadays, green travel is advocated in the society. As a zero-pollution transportation tool, bicycle is favored by many people. However, the large area occupied by mountains and hills in China leads to the time-consuming and laborious situation of bicycle. A similar bicycle elevator in Trondheim, Norway, has a length of 130 meters, and a pedal is set every 20 meters. It can help six people climb up a slope at the same time every minute, and 360 people in an hour. When the rider rises to the end of the ropeway, the pedal will automatically retract below the road surface and return to the starting point through the underground cover. Not only to avoid the risk of collision with vehicles and pedestrians, but also fully automatic operation, do not need operator maintenance. According to local surveys, 41% of residents have experienced a significant increase in the frequency of bicycle travel since the device appeared. Now there are more than 200,000 people using the similar device, so it is safe and stable, easy to be controlled by users, and can obtain a large number of customers [14].

This device is designed for the disadvantages of slow climbing and tiring climbing of bicycles. It not only saves the physical strength of cyclists, but also increases the efficiency and interest of cycling, which is very conducive to cycling activities.

2. System architecture

The device is mainly divided into three modules: photovoltaic power module, power module and auxiliary rising module. Main components include solar photovoltaic panels, energy storage device, pedal, guide rail, DC motor, cable, etc. The structural diagram of the device is as shown in Figure 1.

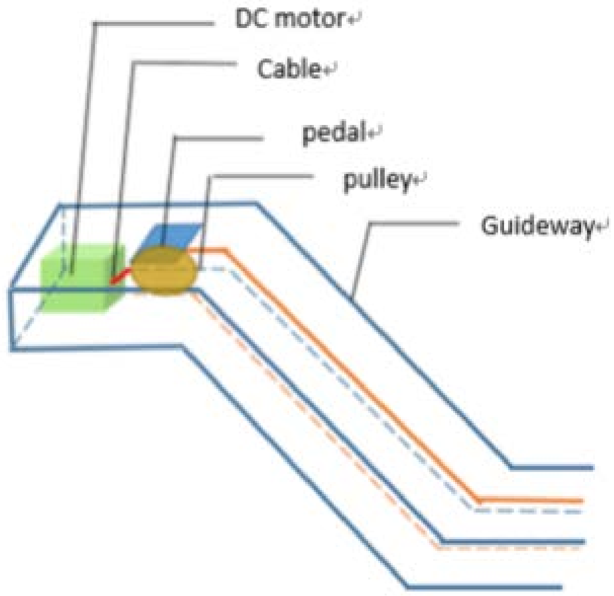

Figure 1. Schematic diagram of device structure

2.1 Photovoltaic power modu*le*

Solar photovoltaic panels installed on platforms and other facilities in areas with high light intensity convert light energy into electricity through the panels. The electricity drives the DC motor equipment to run, which then drives the cables and pedals. The surplus electricity will be stored in batteries for overcast and night use [15-16].

2.2 Power module

The DC motor converts the direct current into the mechanical energy output on the shaft, and the motor rotates the traction cable to enable the pedal to rise [17].

2.3 Auxiliary rising module

The lower part of the guide rail is the working space of the cable

ISSN 2616-5767 Vol. 2, Issue 1: 199-209, DOI: 10.25236/AJETS.020033

and pulley. The pulley is connected with the cable, and the pedal is mounted. The cable pulls the pulley to drive the pedal up. The other end of the cable is connected to the DC motor. The pedal is installed diagonally, and the lower part is occluded with the guide rail to provide users with stable support. The pedal has built-in sensors that operate through a pressure starter that senses the rider's footsteps. The user puts his foot on the pedal when using the device, and the sensor transmits the signal to the DC electric machine to start working.[18-20]

3. System operating principle and photovoltaic cell capacity selection

A solar cell phalanx is composed of multiple components to obtain higher voltage and current. Schematic diagram of system circuit is shown in Figure 2.

The solar photovoltaic part includes solar cells, controller, power storage circuit, DC-AC conversion circuit, etc

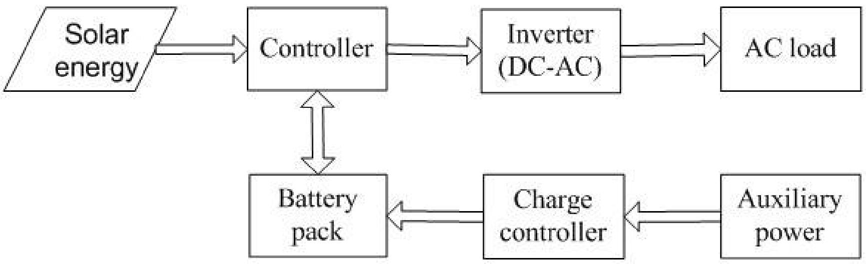

Figure 2. System operation flow chart

Solar energy converts light energy into electrical energy, through the role of the converter, will be part of the electrical energy stored in the storage battery, according to the needs of load adjusting power and use the inverter circuit convert alternating current (ac) used for load, if the system is in the rainy weather, the controller transfer the battery storage of electricity to power a load and use the inverter switch circuit, in order to maintain normal operation of the system.

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ISSN 2616-5767 Vol. 2, Issue 1: 199-209, DOI: 10.25236/AJETS.020033

4. Motor executive circuit

4.1 Schematic circuit diagram

The specific circuit diagram of motor operation is shown in figure 3.

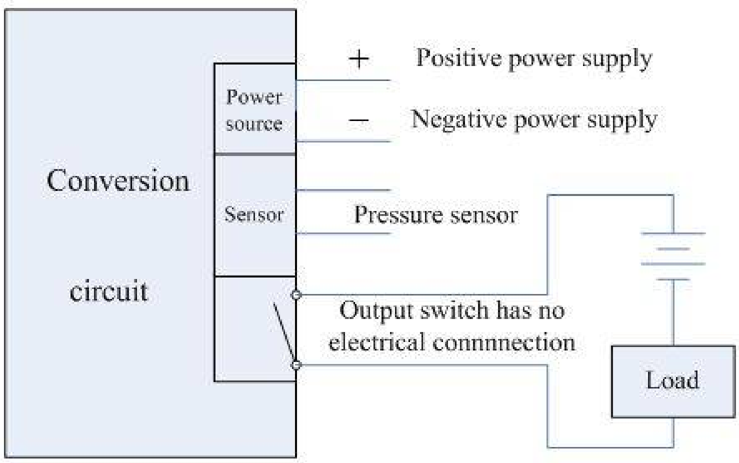

Figure 3. Motor execution circuit diagram

The energy storage circuit diagram is shown in figure 4.

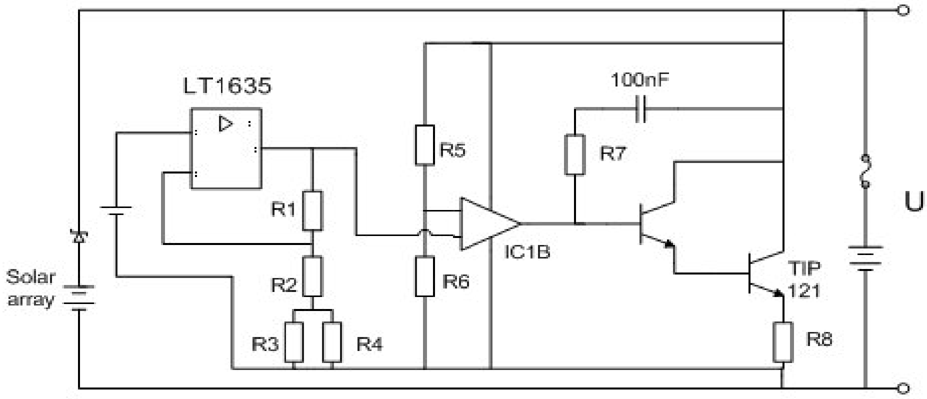

Figure 4. Energy storage circuit diagram

DC-AC conversion circuit diagram is shown in figure 5

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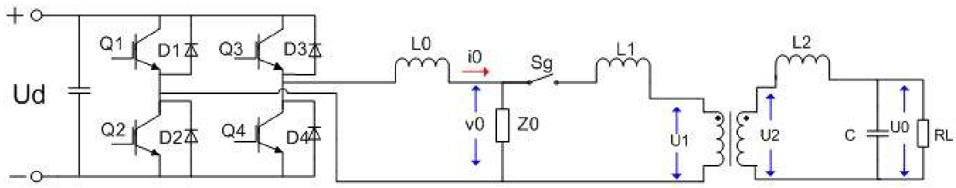

Figure 5. DC-AC conversation diagram

4.2 Circuit principle

As shown in figure 5. Q1 and Q4 are a pair of bridge arms, Q2 and Q3 are a pair of bridge arms.

Each bridge arm consists of a controlled IGBT and an anti - parallel diode. There is enough capacitance on the DC side and the load is connected between the bridge arms.

Set the initial moment, to IGBT Q1and Q4 trigger signal, make it conduction. Then bridge armQ1, load, bridge armQ4 constitute a circuit. At some point, Q2 and Q3 are given a trigger signal, and Q1 and Q4 are given a cutoff signal. However, due to the large load inductance, the current passing through it cannot be mutated, so the diode D2 and D3 conduct continuous current. When the current gradually decreases to zero, the bridge arm Q1 , Q4 is switched off, and the bridge arm Q2,Q3 is switched on, forming a loop to realize commutation.[21]

The working waveform of single-phase bridge inverter is shown in the figure 6.

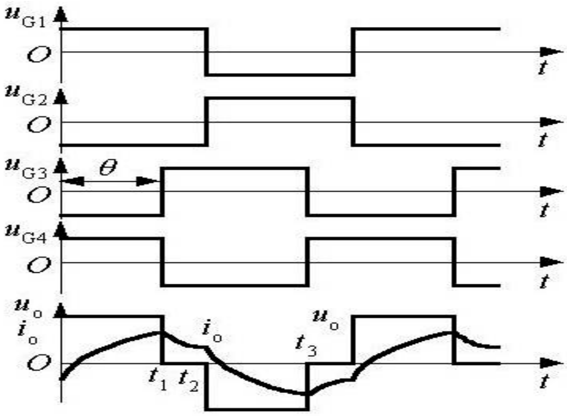

Figure 6. Voltage waveform

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The voltage waveform is quantitatively analyzed, and the rectangular wave with amplitude a is converted into Fourier series.

$$u_0 = \frac{4U_d}{\pi}(\sin\omega t + \frac{1}{3}\sin 3\omega t + \frac{1}{5}\sin 5\omega t + ...) \quad (1)$$

Where, Ud is the port voltage,U01m is the amplitude of the fundamental wave and U01 is the effective value of the fundamental wave.

$$U_{01m} = \frac{4U_d}{\pi} \quad (2)$$

$$U_{01} = \frac{2\sqrt{2}U_d}{\pi} \quad (3)$$

4.2 Analysis of circuit principle

Through the circuit experiment shown in figure 3, the motor running process under pressure is simulated. The load is connected to the DC motor with rated voltage of 12V, and the power supply is connected to the DC power supply of 12V.In the stress area of the circular pressure sensor with a diameter of 18.23mm, the pressure substance is uniformly applied from zero, and the voltage and current changes at both ends of the motor are recorded. When the pressure increases to 1.186N, the motor starts to rotate. At this time, the voltage at both ends of the motor changes from 0V to 11.82V and remains unchanged.

Specific current conditions are shown in figure 7.

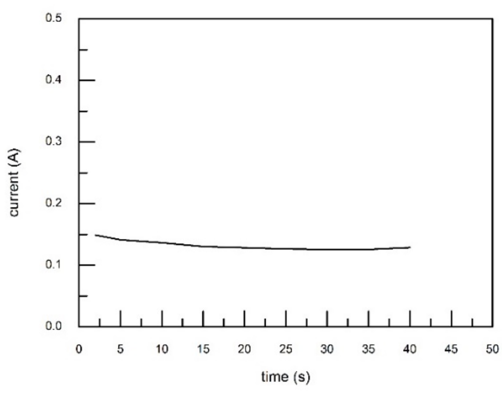

Figure 7. Motor end current variation

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When the motor is started, the running speed is very low and the magnetic impedance (inductance generated by the interaction between the coil and the permanent magnet) is very small. When starting, the coil temperature is low, the resistance itself is small, the overall resistance is small, so that the current is large. As the motor speed increases, electrical energy is converted into mechanical energy and a small amount of heat energy, and the current finally tends to be stable and operate normally. Reduce the power supply voltage and reduce the motor speed. When the power supply voltage is reduced to 5.50V, the motor stops rotating and the voltage at both ends of the motor is zero. Maintain the pressure required by the trigger switch and gradually increase the voltage from zero. When the power supply reaches 8.50V, the motor will resume rotation and the voltage at both ends of the motor is 8. 41V.This process simulates the actual operation process of the device. When the voltage of the actual photovoltaic power generation board changes, when the voltage is not lower than a specific value, the motor will still maintain rotation, and the speed will be reduced accordingly.

When the voltage of the photovoltaic panel is higher than a certain threshold, the motor will still operate normally when the trigger voltage of the pressure sensor is reached, and the cable and pedal will be pulled up.

5. Simulation test and analysis

The running state of the device mainly depends on the voltage of the end motor and the pressure trigger of the pedal. Firstly, a simple guide rail with a length of 5m was prepared and put on the top to form a certain slope.

The slope calculation formula is

$$tan\,\alpha = H/L \tag{4}$$

In the formula, α is the slope angel. H is the height differences. L is the horizontal distance.

A DC motor is connected at the top, and the motor is connected with the pedal by a steel core cable. The pedal engages the guide rail tightly. The motor is powered by solar photovoltaic panels and batteries, with an area of $0.2m^2$.

In the environment temperature is 25 ℃, the light intensity as the AM1.5, under the condition of $1000w/m^2$ participants on the bike to pressure on the pedal, the top end of the pedal pressure sensor triggered when the pressure of 196.78 N and above, motor by steel reinforced rope traction pedal rise.

The relationship between variables in the process from starting to constant speed is

$$F - Mg\sin\alpha - \mu Mg\cos\alpha = Ma \qquad (5)$$

In the formula, F is the traction of the motor. M is the mass of the object (ignore the pedals). g is the gravitational acceleration. μ is the dynamic friction factor. a is the acceleration of the mass.

When the object is rising uniformly, $a = 0$, namely, $F = Mg\sin\alpha + \mu Mg\cos\alpha$.

Considering the change of the lubrication degree of the motor shaft between the pedal and the guide rail (the dynamic friction coefficient fluctuates between 0.07 and 0.10), the traction force of the motor will change with the change of the slope Angle and the weight of the object.

According to the actual work done by the motor, the power required by the solar photovoltaic panel can be obtained when the number of people increases. The figure above shows the relationship between the system power utilization efficiency and load power with or without controllers.

6. Conclusion

The use of solar photovoltaic power generation as a power supply device reflects the concept of green environmental protection and the combination of nature and science and technology, the calculation of the required capacity of the power generation system, and determine the load power consumption, the use of the controller for the control of the circuit, the reasonable distribution of energy storage and consumption, so that the use of energy efficiency to a higher level . Through the design of the bike uphill auxiliary device, the problem of cycling uphill fatigue and slow climbing is greatly solved.

Solar photovoltaic power generation saves energy and protects the environment. Meanwhile, it is very convenient to use with Shared

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bicycles. This will accelerate the development of the sharing industry, and improve the efficiency of urban transportation. It will reduce the pressure of urban congestion, and increase the penetration rate of bicycles in hilly and mountainous areas. Due to the simple assembly, simple structure, easy parts processing, maintenance costs, there is a huge market.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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