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Wind-Solar Hybrid Streetlights

Wang Liangchen

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Abstract

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Author(s) Wang Liangchen			
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Supervisor(s) Olli-Pekka Kähkönen ; Ritva Käyhkö			
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Abstract

The wind and solar energy are called green energies. They have many advantages and have become important newly arisen energy types. When using wind and solar energy alone, they greatly depend on the weather. But the wind-solar hybrid system can make up for this disadvantage, because it can effectively use the solar energy when daytime and summer, and the wind energy when night and winter.

The wind-solar hybrid system was designed in this thesis. This system uses an AC bus. It is permitted to enlarge the system and it can connect the other equipment conveniently. In the thesis it is also designed and analysed the configuration of the wind-solar energy system, the controller, and inverter.

The conclusion of this thesis is to show that the combination of wind and light energy can be effectively. It improves the use of natural resources. It is a good demonstration of the social sustainable development.

Keywords
Solar Energy, Wind Energy, Hybrid Energy systems

SYMBOLS AND ABBREVIATIONS

DC	Direct Current
AC	Alternating Current
PV	Photovoltaic
JB	Chinese machinery industry standard
JB/T	Chinese Machinery Department recommended standard
GB	Chinese national standards
GB/T	Chinese national recommended standards
CJJ	Chinese urban construction industry standard

CONTENTS

1 INTRODUCTION

1.1 The background of wind-solar hybrid streetlights

Energy is the important material base for the national economic development and people's life. In the past 200 years, the fossil fuels (such as coal, oil, natural gas) energy systems have greatly promoted the development of human society. But the human using fossil fuel has brought the serious environmental pollution and ecological damage at the same time. In recent years, the countries all over the world come to realize the importance of energy to the human, and are more aware of the environmental and ecological damage caused by the use of conventional energy. Countries that are based on national conditions, began to governance and alleviate deterioration of the environment, and put the development and utilization of renewable, pollution-free new energy as an important content of sustainable development. The wind-solar hybrid system is a complementary by using wind and solar energy resources. It is a new kind of energy power generation system with high ratio of performance to price. It has a very good application prospect. It is well known that traditional non-renewable energy sources (such as coal and oil) will run out in the end. Electric energy is mainly relying on hydroelectric and thermal power. While the new energy sources such as wind and solar energy has not been popularized, urban road lighting and landscape lighting electricity consumption is very large. So urgently it is needed to speed up the construction of wind-solar hybrid streetlights.

1.2 The current situation and development of wind-solar hybrid system

In 1981, Denmark's N.E.Busch and Kallenbach first proposed the mixed use of solar energy and wind energy. Initially wind-solar hybrid system will only make a simple

combination of wind turbines and photovoltaic modules. Because of the lack of detailed mathematical calculation model, at the same time, the system is only for low guarantee rate of users. It leads that the usage time is not long. Subsequently, N.Aksarni according to the principle of probability, the approximate estimates of the potential of solar energy and wind energy are gotten and it provides data support for the wind-solar hybrid system of research and utilization. In 1982, Chinese Yu Huayang proposed a wind power and solar generator energy conversion device; wind-solar hybrid system's research entered the stage of practical application. With the deepening of the wind-solar hybrid system research, it produced a series of preliminary research achievements. In the aspect of software development, at the university of Zaragoza Spain, c + + language was used to develop a set of complementary for wind and solar energy, a diesel engine power generation system based on genetic algorithm optimization system (software).Then Colorado State University and the National Renewable Energy Laboratory cooperation developed hybrid2 application software. Hybrid2 itself is a very good software. It can simulate the operation very precise. It obtained the 1 year 8 760 h of simulation run results when the hybrid power system structure, load characteristic, and the installation location of the wind, solar radiation data were input.

China has a vast territory, rich in wind and solar energy resources. It is estimated that in the China's land area it can be developed wind energy reserves about 2.5×10^8kW. The sea can develop wind energy reserves about 7.5×10^8kW. The annual sun radiation projected on the ground can be as high as 1.05×10^{18} kWh (3.78×10^{24}J), equivalent to 1.3×10^6 million tons of coal. The application mode of wind and solar energy is varied; the one used for power generation is the most common form. China's wind power has developed rapidly: in 2006, China's total wind power capacity reached 2.6 GW. (Chen Jieshun 2006.) In 2014, the newly installed wind power capacity was over

7.0 GW. Expected by the end of 2015, the total installed capacity of wind power will reach 100 GW which will be put into operation. Due to the low energy density of solar photovoltaic power generation, and the limited existing solar panels photoelectric conversion efficiency (usually less than 15%), it is needed to use a large area of solar panels when getting some power. So obtaining units of power will take a lot of area (6 ~ 10m^2 / kW) and it is costly (35 to 45 yuan / watt). This limits the large-scale application of solar photovoltaic power generation. In recent years, with the improvement of solar photovoltaic industry scale and energy conversion technology, solar photovoltaic power generation cost has decreased. (Qi Fa 2005.) Rapid development of wind and solar power generation technology and its industrialization has laid a good foundation for the application of wind-solar hybrid system.

At present, China is running wind-solar hybrid systems for example are: Tibet NaQu village wind-solar hybrid power station and Inner Mongolia miniature wind-solar hybrid power system, etc.

1.3 The significance of wind-solar hybrid streetlights

With the rapid economic development, energy consumption has increased year by year. Conventional energy is faced with increasing exhausting. The urgent need for new clean renewable energy exists. In the current number of renewable energy and new energy technology development, wind and solar energy's potential is the largest, and has the most development value. They are an inexhaustible renewable energy.

First, using a single solar or wind power, there is a problem that, when it is winter, the wind is rich but the solar energy is lacking; when it is summer, they are just the opposite. So, wind and solar energy can be very strong complementary for each other.

This complementarity makes the wind-solar hybrid system the best match in terms of resources. Secondly, because the wind power system and solar power system's battery and the inverter can be generic, the wind-solar hybrid system can reduce the cost, the independent power system, and the reliability is much higher. Wind-solar hybrid streetlights as a practical application can not only make full use of resources, beautify and protect the environment, but also reflect the city's modernization. So the promotion of wind-solar hybrid streetlight construction has quite positive significance.

A wind-solar hybrid streetlight has three main significances:

1) Social benefit: wind-solar hybrid streetlight is a high-tech environmentally friendly product. Installing the wind-solar hybrid streetlight is done, not only in conformity with the government's environmental protection concept, but also it reminds people to protect the environment.

2) Economic benefit: It uses and produces power by itself. After the construction of a one-time investment, we can get a long-lasting benefit. Changing the traditional streetlight system laid on the underground cable power supply way saves a lot of manpower and financial resources.

3) Environmental benefit: Each traditional streetlight spends 1825 kWh power in 10 years. According to the standard thermal coal consumption (400g / kWh) to calculating, the standard coal consumption will be 7.3 tons. So a city center will consume 876,000 tons of standard coal just in 10 years, It will let out 3 million tons of carbon dioxide, 17,500 tons of sulfur dioxide, 13,000 tons of nitrogen dioxide, and so much

powder and impurity. But when using the wind-solar hybrid streetlights, the pollution will be avoided. (Li Ming 2007.)

1.4 The development prospects of wind-solar hybrid streetlights

The government vigorously promotes energy-saving and emission reduction. This gives the best chance for wind-solar hybrid product development. But in contrast of the rapid development of solar products, the number of wind-solar hybrid products applied is very few. The main cause of this situation is stereotypes. People think the cost is too high, and the energy is subject to weather impact. Lighting time can not be guaranteed. These are unable to cover the huge development prospect of wind-solar hybrid streetlights. Some experts believe that wind-solar hybrid streetlight can make up the lack of using wind power and photovoltaic separately. It is the perfect combination of comprehensive development and utilization of new energy. It has a vast market and superior competitiveness.

1.5 The main research content

The main contents are: the design of a wind-solar hybrid streetlight, introducing the function of batteries, controllers and other components, analysis of the application of Wind-Solar hybrid streetlight, and explaining the configuration of wind-solar hybrid streetlight.

2 THE WIND-SOLAR HYBRID STREETLIGHTS

2.1 The principle of wind-solar hybrid streetlights

Figure 1: The Component of wind-solar hybrid streetlights (The Wind-Solar Hybrid Power System)

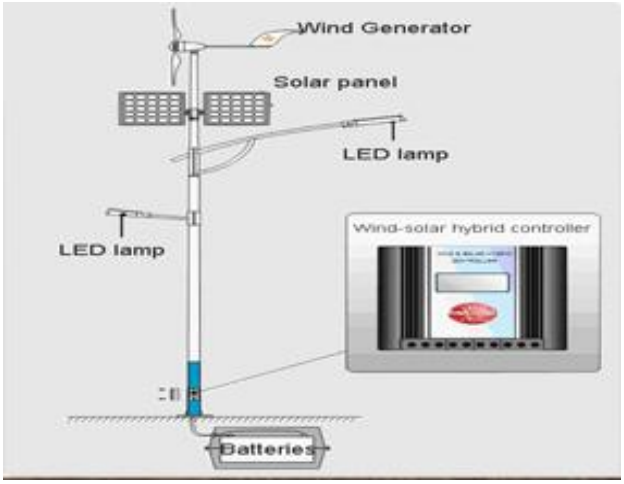

Figure 2: The model of wind-solar hybrid streetlights (Wind-light-system)

Streetlights spend a lot of electricity as the people's livelihood needed. In today's energy crisis, wind-solar hybrid streetlights can solve this problem. But the principle of wind-solar hybrid streetlight is not known for the most of people. Understanding the principles of wind-solar hybrid streetlights can better promote the technology. The wind-solar hybrid system is a kind of wind energy and solar energy into electrical energy device. Wind-solar hybrid streetlights working principle is the following: The sys-

tems use natural wind and solar energy as power. Wind wheel absorbs the wind energy to make the wind generator rotating, making the wind energy into electrical energy. The electric current through the controller of the rectifier makes the alternating current into direct current by the voltage stabilizing effect. Then electric power will charge the battery pack, and the battery will store the electric energy. At the same time, the solar energy will transform into direct current by using photovoltaic affect. The electric power will be used for the load, or stored in the battery for standby.

2.2 The configuration of wind-solar hybrid streetlights

The main components are: solar photovoltaic panels, a lead-acid storage battery, a control system, an inverter, a wind power generator, a lamp-post, and a light source.

2.2.1 Solar photovoltaic panels

The 10W/12V, 0.1 m^2 silicon photocell can convert solar energy into electrical energy, which belongs to a semiconductor element. It is a kind of polycrystalline silicon solar panels, with conversion efficiency as high as 15%. The solar photovoltaic panels have many characteristics: damp proof, stable operation, no need of maintenance etc.

Solar energy conversion is the application of the P-N junction photovoltaic effect. First a simple description of P-N junction diode is made. As shown Figure 3, it is an ideal P-N junction diode, the current - voltage (I-V) characteristic diagram, which corresponds to the following equation （Chen Jieshun 2006.):

$$I_{pn} = I_s\left[\exp\left(\frac{qV_{pn}}{nkT}-1\right)\right] = I_s\left[\exp\left(\frac{V_{pn}}{nV_T}\right)-1\right] \qquad (1)$$

I_{pn}, V_{pn}: p-n junction diode current and voltage

K: Boltzmann Constant (1.38×10^{-23}J/K)

q: the electronic charge (1.602×10^{-19}C)

T: absolute temperature

I_s: the equivalent diode reverse saturation current

V_T：Thermal Voltage (25.68mv)

Solar photovoltaic panels convert sunlight into electricity. It depends on the quantum (Photons) of natural light，and each photon energy is E_{ph} (Chen Jieshun 2006.):

$$E_{ph}(\lambda)=\frac{hc}{\lambda} \qquad (2)$$

h：Planck Constant (4.14×10^{-15}eV • S)

c：speed of light (3×10^{8}m/s)

λ : Photon wavelengths

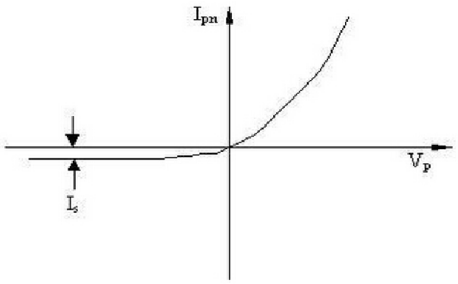

Figure 3: The current - voltage (I-V) characteristic diagram

However, not all photons by the solar cell can successfully convert light energy into electrical energy, because in a different spectrum, energy carried by photons is different. When photons carry energy greater than band gap energy, the electron will become conduction band from valence band, and the "current" comes out. So when the photon energy is larger than the band gap energy, the photoelectrons can convert into electricity.

2.2.2 Lead-acid storage battery

Battery selection requirements are: light weight, small volume, high energy conversion rate, slow self-discharge, charge discharge cycle number (the service life is long) etc. Some special requirements are such as low temperature large discharging current, simple maintenance or no maintenance, particularly slow self-discharge etc.

Using the battery, the most important is the effective use of the charge and discharge characteristics. Effectively, the scientific use of battery not only improves the service efficiency. Prolonging the service life is critical, but also it can improve the working efficiency of the whole system. Its function is to store the electricity generated by wind power generator, to be released when needed.

Because working in low or high temperature environment will affect the working performance of the battery, especially in low temperature, its working capacity will decrease a lot, which is decided by the characteristics of a storage battery. Therefore, the battery installation is adopted under the ground, under 1 meter -1.5 meters. The temperature of the environment is affected by geothermal effect. It plays a certain role in the "thermostat". In winter the temperature is higher than above ground; in the hot summer temperature is lower than above ground. It is conducive to the performance of a battery. (Qi Fa 2005.)

The rated capacity of the battery C is the product of discharge current A and the discharge time hours h. the same battery uses different discharge parameters, so the rated capacity is different. In order to facilitate the description, measurement and comparison of the battery capacity, it must be set uniform conditions in advance.

Supposed that the battery works 8 hours a day and rainy days need work three days continuously, so that we can calculate the capacity of the battery. Other uniform conditions are: the capacity is 12V/200Ah; full sealed maintenance free lead-acid battery is 12V; the battery discharge cannot be less than 10V; the charge is not higher than 16V. (Qi Fa 2005.)

2.2.3 Control system

The microcomputer control system is the core content of the whole design. It is the basic guarantee for the safe operation of the whole system. Because the system is running by the application of environmental requirements, it requires the maintenance to be free. So no matter the hardware or software systems, it has to protect the system. Such is the battery voltage control in the hardware design, using the DC battery charging require voltage control between 10 ~ 12 ~ 16V, so that the system will not to be burned. So voltage control is used to ensure the battery do not over charge and is without excessive discharge.

The system uses a wind-solar hybrid intelligent controller, with high charge and a variety of self-protection function.

Figure 4: Wind-solar hybrid intelligent controller (Wind-solar hybrid intelligent controller)

The specific technical parameters (Wind-solar hybrid intelligent controller):

Model: EPFG24V-20

Wind power generator input: AC = 50V, P = 300W

Photovoltaic battery input: DC 50.0Vpm，I≤15A

Output voltage: DC 28.0V

Input overvoltage protection value: AC 50±5V

Output overcurrent protection value: DC 20A±1A

Battery under voltage protection starts voltage: DC 21.0±0.3V

Battery under voltage protection recovery voltage: DC 23.0±0.3V

Full battery protection starts voltage: DC 28.0±0.2V

Wind power generator unloading box power: 400W

Dimensions: 300×360×15mm

The role of the controller is to control the whole system is working state, and over charging protection, over discharging protection functions to the battery. This can be seen from the chart (Figure 5).

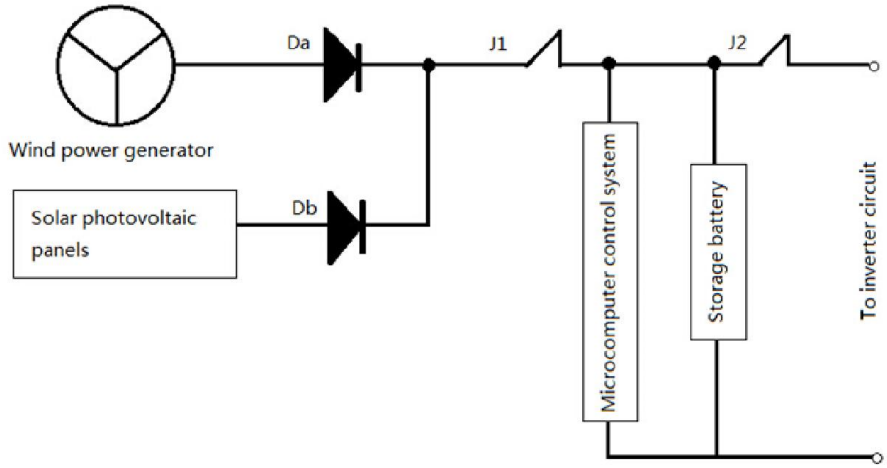

Figure 5: The principle of control circuit

A single chip microcomputer system detects the battery voltage at both ends: If the battery is overcharge, it makes the relay J1 action. The charging circuit will be disconnected, and it will not supply power to the battery. If the detected result is the battery over discharge, it makes the relay J2 action. It will disconnect the load circuit, and is no longer supplying power to the load, and it will charge the battery.

In order to protect the system, the control circuit have increased the diodes Da and Db. The role of Da is a three-phase rectifier diode group. This is because the battery power supplying requirement is DC voltage. But the wind power generator production is three-phase AC. In order to convert AC power to DC power, the control circuit is added to the three-phase rectifier diode group. The role of Db is to prevent the destruction of the solar photovoltaic panels by the backward current.

2.2.4 Inverter

The role of the inverter system is to make storage battery DC into 220V AC. It ensures that the equipment can get the normal use of AC. At the same time, the inverter also has the automatic voltage regulation function. It can improve the quality of power supply of wind-solar hybrid system. In the circuit structure of an inverter, the main two forms are a power frequency transformer and a high-frequency transformer. The inverter is a kind of power electronic equipment for the wind-solar hybrid system. Its anti-overload and anti-shock capabilities are weaker, and it is the most easily faulty unit.

2.2.5 Wind power generator

A wind turbine takes the wind power into mechanical energy, then the mechanical energy goes through the wind power generator and the electrical energy will be produced. After that, the electrical energy goes through the controller to charge the battery. Finally, the electric current goes through the inverter and supplies power for load. The wind power generator is composed by the head, rotor, tail vane, and blade. Every part is very important; the functions of each part are the following: Blade contacts the wind and makes wind energy into electricity through the head. Tail vane lets the blade locate always against the wind, so as to obtain the maximum wind energy. Rotor can make the head rotate flexibly, in order to achieve the function of the

tail vane to adjust the direction. The head of the rotor is a permanent magnet. The stator winding cuts magnetic lines of force to generate electricity.

2.2.6 Lamp-post

The wind power generator and solar photovoltaic panels is a sign of the combination of wind solar hybrid streetlights. Lamp posts are usually designed as free-standing poles. It can ensure the wind power generator and the solar cell operation smooth and safe. Wind power generator is located at the top of the lamp post, and the solar photovoltaic panel is located in the middle of the lamp post.

2.2.7 Light source

Figure 6: Light source (Light source)

- Texture of material

The reflector, the lamp and the radiating body are made of high purity aluminium. The glass cover is made of high strength tempered glass. Also need the high power LED

light source and the high efficiency of imported constant current source as the material.

- The light source must meet the following two conditions:

1) It has long life and low light decay, so as to reflect the high quality of lighting system.

2) For as much as possible to reduce the initial investment cost, the light source needs to reduce the wafer area and the battery capacity. The overall cost will drop if the actual working current source at the same power is as small as possible. So the proportion of the light source in the cost of the whole wind solar hybrid streetlight system is very small.

- Characteristic

The light source uses a single powerful LED (10W - 40W) as the light source, and it uses a special multiple chips integrated type light source design.

The light source uses the built-in radiator and radiating ventilation hole combined. It not only keeps the lamps and lanterns beautiful, but also can ensure the lamp body heat flow and the reliability of LED light source.

For shells it is used aluminium alloy pressure forming. It is effective in cooling and is waterproof, dustproof. The surfaces of the light have a treatment of anti-ultraviolet corrosion. It will be no glare and no stroboscopic. It can eliminate the visual fatigue and the disturbance of ordinary street lamps. The driving will be safer.

2.3 The advantages and disadvantages of wind-solar hybrid streetlights

The advantages of wind-solar hybrid streetlights:

- It has super power and the brightness equivalent to 150W-250W incandescent lamp. It can be lit 8 hours a day. It can normally work 9 days in the continuous rainy weather.
- It has the application of photoelectric intelligent controller with charge and discharge protection function, the photosensitive self-control device and time control device. So that the product can save energy effectively, increase effective lighting time and reduce the cost of production.
- The unit of central controller uses a TEC1208 chip and establishes the global different latitudes year-round sunshine time data in an intelligent controller. Inputting the region latitude in the controller, adjusting the right year, month, day and the on / off time, then it can automatically track the ambient light year by year.
- Wind-solar hybrid streetlights have the advantages of high efficiency, long service life, the breeze start, maintenance free, light weight, easy installation, anti-strong wind, low noise, rust proof, anti-corrosion and waterproof. The solar energy resources throughout the world are inexhaustible. It is not depending on the laying of cables. It also has the advantages of zero carbon emissions, small investment, emission reduction and environmental protection. And it especially suits for municipal lighting renovation projects and highway unmanned maintenance areas.

The disadvantages of wind-solar hybrid streetlights:

- Expensive investment: the individual equipment cost is too high, and the equipment needs professional personnel for maintenance and repair. Once faults occur, it will cause a lot of expenditure.
- Big noise: When the wind turbine is running at night, it will cause some noise, affecting the people's normal life and sleep. But with the development of technology, the problem will be solved in the future.
- Weak lights: In the continuous rainy weather, it is difficult to get enough sunshine. Generating capacity cannot be guaranteed, so that the lamp light is faint.

3 THE DESIGN PLAN OF WIND-SOLAR HYBRID STREETLIGHTS

3.1 The design principle

The design is according to the People's Republic of China industry standard "CJJ45-2006" 《city road lighting design standards》.

3.2 The design requirements

The wind-solar hybrid streetlights must have the low self-discharge rate, high deep discharge, and strong capacity recovery ability. Battery life must be over five years. The warranty period is three years. The main technical performance have reached or exceeded the standard JB/T9653 - 1999.

3.2.1 Solar photovoltaic panels technical requirements

The solar photovoltaic panels must be consistent with International Electro technical Commission lEC61215:2005 and lEC61730:2004 standard.

Under the standard conditions Atmosphere mass: AM=1.5, Standard of light intensity: E=1000W/m2, Temperature: 25 + 1℃, no uniformity Irradiation on the face: ≤±5%.

The solar photovoltaic panels will have excellent anticorrosion, windproof, waterproof and hail suppression ability.

3.2.2 Wind power generator requirements and performance parameters

The wind power generator must meet the technical conditions of the Chinese national standard GB/T10760.1-2003 requirements. (The Chinese national standard)

- GB 8116-1987 《Wind turbine types and basic parameters》
- GB/T 13981-92《General requirements for wind turbine design》
- GB 17646-1998《Safety requirements for small wind turbine》
- GB/T 19068.1-2003《Off grid wind turbine，the first part: technical conditions》
- GB/T 19068.2-2003《Off grid wind turbine，the second part: test methods》
- GB/T19115.1-2003《Off grid outdoor Wind-Solar hybrid power system》

The blade is made of glass fibre and nylon blend. It uses hot moulding technology to ensure the integrity of the blade. It will have a good flexibility and deformation recovery strength.

The generator should be made of Nd-Fe-B permanent magnet motor.

The operations need to meet the specific environment of coastal operating requirements. It must be anti-wind, waterproof, corrosion resistant, aging resistant, abrasion resistant and convenient installation and use.

3.2.3 Lamp-post design requirements

Lamp-posts must meet the requirements of anti-10 wind strength. This system is applied to road and sidewalk lighting. The design for lamp-post height is 15 meters; the light source will be above the ground at 12 meters. The lower diameter of a lamp-post is not less than 200 mm, the upper diameter shall not be less than 100 mm, and the tube wall thickness is greater than 4 mm (before galvanized). The lamp-post is made of high quality steel. It must use a hot dip galvanized spray pole. It needs more than 10 years of working life. At the same time, the design can be referred to the following standards: (The Chinese national industry standard)

- CJJ45-9 《City road lighting design standards》

- CJJ89-2001《Specification for construction and acceptance of city road lighting project》

Because the wind-solar hybrid streetlight has its particularities, the wind power generator is installed in the top of the lamp-post. Components are installed in from the ground 7 meters above. The equivalent vertical surface will bear the wind pressure. It will make some horizontal shear force to the whole lamp-post. Because the calculation parameters of wind pressure are multiple, it is difficult to calculate it. With reference to the actual operation experience, the pole wall thickness should be 4 mm.

3.2.4 Environmental conditions

- Height above sea level: ≤5000m
- The temperature of the environment: -50℃_+70℃
- The wind speed: 35m/s
- Relative humidity: 80%
- The seismic grade:8

3.3 The parameter calculation

3.3.1 The calculation of solar photovoltaic panels

The silicon solar panel capacity (C) is the flat plate type solar panels power (WP). Electricity H (Wh) power value depends on the load of 24h energy consumption. The rated power of load and the consumed load of 24h power decide the consumption capacity P (Ah). Considering the effect of the average daily hours of sunshine and rainy days, the working current of the solar cell array IP (A) can be calculated.

The nominal voltage of a battery is selected by the load rated power. The battery nominal voltage determines the number of batteries in series and the battery float voltage VF (V). Taking into account the solar battery temperature voltage VT (V) and the reverse charging diode P-N junction voltage drop VD (V), we can calculate the working voltage VP (V) of solar cell array. VP (V) and IP (A) can decide a flat plate type solar panel power WP. The calculated results can determine the number of blocks in series and paralleling group number of silicon cell plate. The specific calculation steps are as follows (The Chinese solar photovoltaic industry analysis and investment consulting report 2008):

Calculation of load capacity (P) of 24h consumption:

$$P = \frac{H}{V} \tag{3}$$

Calculation of solar array operating current:

$$IP = \frac{P(1+Q)}{T} \tag{4}$$

Q: The rainy period surplus coefficient=0.21～1.00

T: Hours of sunshine daily

Determining the battery float voltage VF:

$$VT = \frac{2.1}{430(T-25)VF} \qquad (5)$$

Calculation of working voltage of the solar battery array VP:

$$VP=VF+VD+VT \qquad (6)$$

VD=0.5～0.7

VF can be found in (5)

The solar battery output power of array WP:

$$WP=IP*UP \qquad (7)$$

The volt ampere characteristic curve is strongly nonlinear. The rated power of solar array is defined in the following conditions: Solar S=l000W /m^2; solar cell temperature T=25; atmospheric mass AM=1.5.

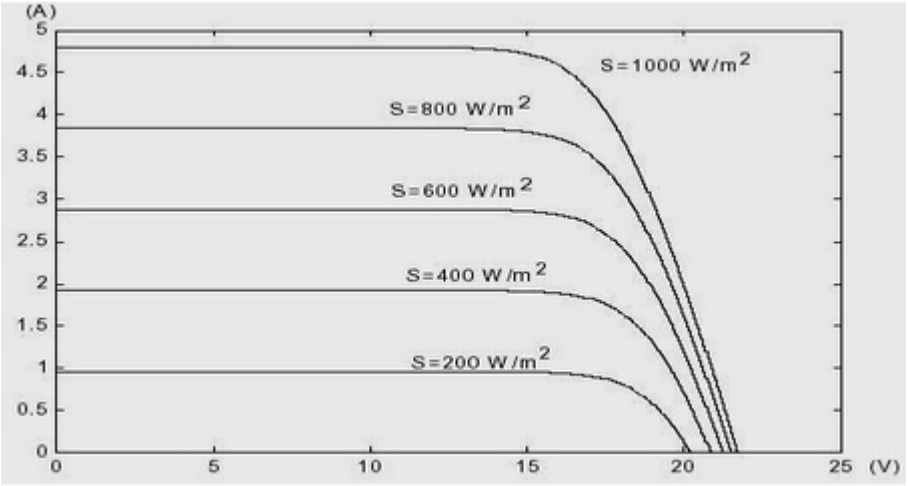

Figure 7: I-V characteristic curve of solar cell array

The maximum power output of solar cell array is defined as its rated power. When S<l000W /m2, it only changes the intensity of sunlight and keeping other conditions (such as solar cell temperature and atmospheric mass etc.) the same. Temperature and sunlight intensity have effect on the I-V characteristic of solar cell array.

3.3.2 The calculation of generating capacity

A 20 metres width configuration is made as an example. The calculated conditions are the annual wind speed above 3 m/s and time more than 3500 hours. The amount of 1kW solar panels converting solar radiation is 4500-5500 MJ/year. The calculation takes the total solar radiation conversion to be 4500 MJ/year for safety reasons. So the average daily power generation of a solar panel configuration should be:

Q1=4500/365/3.6*0.4*0.8=1.1kWh (0.8 is safety coefficient, 04 is system using ratio)

Because the road lamp mounting points of condition is uncertain, so the underestimation of annual average wind speeds for lamp mounting points are 4 m/s. The total generating capacity of wind power generator is 223 MJ/year. The average daily generation capacity of the wind power generator configuration should be:

Q2=223/365/3.6*0.8=0.489kWh (0.8 is safety coefficient)

So the average total power generation capacity of the wind-solar hybrid streetlight configuration is 1.589kWh/day.

3.3.3 The detection of battery charge state

The accurate judgment of the charge or discharge state of the battery is a prerequisite for effective use of a battery and for selecting the appropriate method of charging. At present, most of the solar controllers are used to detect the battery terminal volt-

age, and it is the basis for automatic switching of the charging method. But as everyone knows, the terminal voltage of the battery is affected by many factors especially in the charging process. The battery terminal voltage is restricted by the terminal voltage of solar cell, and it can't reflect the state of charge accurately. For example, when the system temperature is high, it is easy to observe the phenomenon that the battery capacity is not full but cannot been charged into, it's namely "virtual full". It is difficult to detect the battery charge state accurately. It will affect the normal working of the whole system. For this reason, people have proposed a new detection method -- off-line detection. In the theory of lead-acid battery, the battery electric potential can be expressed as (Fu Yanlin, Xie shuang, Dong Jie 2012.06.):

$$E = E0 + \frac{RT}{nF} \ln \frac{\partial(H_2SO_4)}{\partial(H_2O)} \qquad (8)$$

E: The electric potential of battery (V)

E0: The standard electric potential (V)

R: The molar gas constant

T: Temperature (K)

F: The faraday constant

n: The number of electron gain and loss in the electrochemical reaction

It can be seen from Formula: electric potential is related to the concentration of sulfuric acid, it is also related to state of charge. The battery open circuit voltage is closed to the electromotive force in value. According to the related literatures, the battery open circuit has a good linear relationship between the steady-state voltage and charge state. Therefore, the open circuit voltage of the battery can estimate the charge state of battery.

3.3.4 The calculation of lamp-post strength

- The known design conditions:

Design maximum wind speed: U=40 m/s

Material: Q235 (ordinary carbon structural steel)

Allowable stress: [σ] = 235 MPa

Modulus of elasticity: E= 206000 N/m^2

The height of lamp-post: 15000 mm

Equivalent pole diameter: De= (d+D)/2 (lamp-post lower half section is a cone:

d=114 mm， D=220 mm)

- Wind pressure:

$$P=U^2/16=980\ (N/m^2)$$

- Windward area:

  $S_{lamp\text{-}post}$ = (D+d)*H/2 =1.67(m2)

  $S_{bifurcate\ pole}$=0.228(m2)

  S_{Lamp}=0.6(m2)

- The maximum moment of force of the lamp-post root:

  Height of center of gravity: Hx=(2d+D)*H/3(D+d)=4.47(m)

  $M_{lamp\text{-}post}$ =P*$S_{lamp\text{-}post}$ *H_X=7317.333333 （N • m）

  M_{Lamp} =P*S_{Lamp} *H_X=2628.982036 （N • m）

  $M_{bifurcate\ pole}$ =P*$S_{bifurcate\ pole}$ *H_X=999.0131737 （N • m）

  M_{total} =$M_{lamp\text{-}post}$ +M_{Lamp} +$M_{bifurcate\ pole}$ =10945.32854（N • m）

  (M: Torque)

- Strength check:

  W=0.000143886 (The modulus of section bending);

  б=M/W=76069694.48(Pa)

  Safety coefficient: K= [б]/б=3.09>1.5

Because the safety coefficient K calculated is greater than 1, the strength is safe.

4 THE APPLICATION EXAMPLES IN CHINA

With the continuous development of wind-solar hybrid streetlight technology, it promotes its practical application. In China, many places have used this kind of streetlights. The following are examples of application:

Figure 8: Guangzhou International Convention and Exhibition center

(Street lamp case)

Figure 9: Guangxi Nanning International Convention and Exhibition center

(Street lamp case)

Figure 10: Ningbo xiangshan big bay (Street lamp case)

Figure 11: Qingdao Olympic sailing base (Street lamp case)

5 CONCLUSIONS

Wind energy and solar energy are renewable. They are non-polluting and zero emission new energies. They have gradually become the main energy source the future of the world is using. Wind-solar hybrid streetlights are a fairly typical comprehensive application. Their main components are solar photovoltaic panels, a lead-acid storage battery, a control system, an inverter, a wind power generator, a lamp-post and a light source. Wind-solar hybrid streetlight working principle is: The systems use natural wind and solar energy as power. Wind wheel absorbs the wind energy to make the wind generator rotating, making the wind energy into electrical energy. Electric current through the controller of the rectifier makes the alternating current into direct current by the voltage stabilizing effect. Then electric power will charge the battery pack, and the battery will store the electric energy. At the same time, the solar energy will transform into direct current by using the photovoltaic effect. The electric power will be used for the load, or stored in battery for standby.

From the sources of energy, solar energy and wind energy are highly complementary in time and geographically. Daytime sunlight is the strongest, but the wind is very small. In the evening after the sunset, the light is very weak, but because the surface temperature changes, the wind power are stronger. In summer, the sun light is strong but wind is small. In winter, the sun light is weak but there is enough wind. So the wind-solar hybrid streetlight system is an independent system based on of the best resource conditions.

The main works of this thesis are as follows:

- The thesis has introduced the research background, purpose and significance of this topic. It has summarized the domestic and foreign research status and development trend of the wind-solar hybrid system.

- According to the wind power system structure, it has analyzed the wind electronic systems, photovoltaic electronic system and the principle of each part of the battery, and also some basic characteristics of wind generator and photovoltaic arrays.

- According to the practical application of the wind-solar hybrid streetlight, the related data has been calculated and designed, getting a specific understanding of systems theory.

REFERENCES

Literature:

(Chen Jieshun. 2006.) <Wind solar complementary power supply system modelling based on fuzzy control>. China: Micro computer information.

(Qi Fa.2005.) <Research and design of the independent running of wind solar complementary power generation system>. China: Application of electronic design.

(Li Ming.2007.) <Research on resources consumption>. Place of publishing or publisher unknown.

(The Chinese national standard) "Electric equipment installation engineering construction and acceptance specification"

(The Chinese national industry standard) "City road lighting design standards"

(The Chinese solar photovoltaic industry analysis and investment consulting report 2008.) China: Chinese investment network

(Fu Yanlin, Xie shuang, Dong Jie.2012.06.) <Discussion on the calculation method of lead acid battery electromotive force>. China: Chinese Electric power press

(Ge Qing. 26. 02. 2014.) Solar and Wind Power in Hybrid Energy Systems in China

Internet Sources:

(The Wind-Solar Hybrid Power System.) [Read 30.12.2014] Available:

http://www.cowinsolar.cn/en/product-detail-261.html

(Wind-light-system.) [Read 30.12.2014] Available:

http://www.china-windturbine.com/nav/wind-light-system.jpg

(Wind-solar hybrid intelligent controller.) [Read 03.01.2015] Available:

http://detail.1688.com/offer/1137128055.html

(Light source.) [Read 08.01.2015] Available:

http://www.youboy.com/s11684291.html

(Street lamp case.) [Read 15.01.2015] Available:

http://www.winpower.cc/cases-view.asp?class_id=33

Appendix 1 Standard Solutions of Wind Solar Hybrid Street Lighting (Ge Qing. 26. 02. 2014.)

Unicorn Series - one power source one Light

Major Component	HY-SWL60A	HY-SWL80A	HY-SWL90A	HY-SWL120A
Wind turbine	HY-400 24V	HY-400 24V	HY-600 24V	HY-600 24V
PV module	60W 12V x 2	90W 12V x 2	100W 12V x 2	140W 12V x 2
Light source	60W LED	80W LED	90W LED	120W LED
hybrid charge controller	12V/10A controller	24V/10A controller	24V/10A controller	24V/15A controller
battery	100AH 12V x 2	120AH 12V x 2	150AH 12V x 2	200AH 12V x 2
Main pole(with power system)	10M, lamp height 6-8M	10M, lamp height 8-10M	12M, lamp height 8-10M	12M, lamp height 8-10M

Pegasus Series - one power source two Lights

Major Component	HY-SWL30B	HY-SWL40B	HY-SWL60B	HY-SWL80B	HY-SWL90B
Wind turbine	HY-400 24V	HY-400 24V	HY-600 24V	HY-600 48V	HY-1000 48V
PV module	60W 12V x 2	90W 12V x 2	140W 12V x 2	180W 24V x 2	180W 24V x 2
Light source	30W LED x 2	40W LED x 2	60W LED x 2	80W LED x 2	90W LED x 2
hybrid charge controller	12V/10A controller	24V/10A controller	24V/15A controller	48V/10A controller	48V/10A controller
battery	100AH 12V x 2	120AH 12V x 2	200AH 12V x 2	120AH 12V x 4	150AH 12V x 4
Main pole(with power system)	10M, lamp height 4-6M	10M, lamp height 4-6M	12M, lamp height 6-8M	12M, lamp height 8-10M	12M, lamp height 8-10M
Regular light pole	4-6M steel pole	4-6M steel pole	6-8M steel pole	8-10M steel pole	8-10M steel pole

one power source two Lights

Triad Series - one power source three Lights

Major Component	HY-SWL20C	HY-SWL30C	HY-SWL40C	HY-SWL60C
Wind turbine	HY-400 24V	HY-600 24V	HY-600 24V	HY-1000 48V
PV module	60W 12V x 2	100W 12V x 2	140W 12V x 2	180W 24V x 2
Light source	20W LED x 3	30W LED x 3	40W LED x 3	60W LED x 3
hybrid charge controller	12V/10A controller	24V/10A controller	24V/15A controller	48V/10A controller
battery	100AH 12V x 2	150AH 12V x 2	200AH 12V x 2	150AH 12V x 4
Main pole(with power system)	10M, lamp height 4-6M	10M, lamp height 4-6M	10M, lamp height 4-6M	12M, lamp height 6-8M
Regular light pole	4-6M steel pole x 2	4-6M steel pole x 2	4-6M steel pole x 2	6-8M steel pole x 2

Sky Driven Series - one power source several Lights

Major Component	HY-SWL40D	HY-SWL60D	HY-SWL80D	HY-SWL90D	HY-SWL120D
Wind turbine	HY-3000 48V	HY-3000 48V	HY-3000 48V	HY-3000 48V	HY-3000 48V
PV module	900W of round panel	900W of round panel	900W of round panel	900W of round panel	900W of round panel
Light source	40W LED x 15	60W LED x 10	80W LED x 7	90W LED x 6	120W LED x 5
hybrid charge controller	12V/10A controller	12V/10A controller	12V/10A controller	12V/10A controller	12V/10A controller
pure sine wave inverter	800W 220/230V	800W 220/230V	800W 220/230V	800W 220/230V	800W 220/230V
battery	200AH 12V x 8	200AH 12V x 8	200AH 12V x 8	200AH 12V x 8	200AH 12V x 8
Main pole(with power system)	15M with round panel in 3 parts	15M with round panel in 3 parts	15M with round panel in 3 parts	15M with round panel in 3 parts	15M with round panel in 3 parts
regular light pole	4-6M steel pole x 15	6-8M steel pole x 10	8-10M steel pole x 7	10-12M steel pole x 6	10-12M steel pole x 5