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The Design of the Household Solar Power Generation System and its Economic Evaluation

Tieyan Zhang, Peng Liu and Zhenhe Ju

Shenyang Institute of Engineering, Shenyang, China
Email: zty@sie.edu.cn

Abstract

Solar energy is an inexhaustible supply of clean energy, and it is one of the most common natural resources of solar energy. To provide a more economical, environmentally form of supplying power for the far away grid and some villa. This paper presents the design of household solar power system. According to the local weather conditions, environment and the demand of the household electricity load. This paper presents how to select the devices according the actual condition. It includes how to choose the model of the inverter, how to determine the battery capacity, how to determine the solar panel module and the construction requirements. Finally, this paper make an economic assessment for this power generation. This economic assessment is about the PR, NPV and the discounted payback period.

Keywords*: photovoltaic, design, PR, NPV, DPP*

1. Introduction

Solar energy is an important renewable clean energy, it is unlimited, not pollution and it could be used by the human. The solar energy per second to reach the ground is up to 500,000 kW. If the human could change the 0.1% solar energy on the ground to electric, and the conversion rate is 20%, the power generation is 5.6×10^{12}kW·h. [6]It is the 40 times than the amount of the energy consumption. In the long run, the solar energy have the best prospects. The past 30 years, the solar energy technology in the researching, developmenting, commercial producting, market developmenting aspects have gained rapid development, the solar energy has became one of, the most rapid and stable development the emerging industry.

2. The Status of Solar Photovoltaic Applications

It is called solar photovoltaic technology that solar energy is converted to electrical energy technology.[9] It is also called photovoltaic. Solar photovoltaic power generation can not only partially replace fossil fuels for power generation, but also can reduce CO_2 and the harmful gas emissions, and it could prevent the deterioration of the global environment. Therefore, the development of solar photovoltaic industry has become one of the best way to solve the contradiction around the energy and economic development in the world. [10]In developed countries such as United States, Germany, Japan, their photovoltaic conversion from the aerospace, defense, industry to civilian. Because of the Germany program of one million roofs photovoltaic, Many families not only use the solar photovoltaic power generation to solve its own power supply, but also pull off one of the private "mini power station", capable of an endless stream of supplying electric power to the utility grid.

In the recent years, the development of China's photovoltaic industry is also very fast. Government withdrew many policies to encourage photovoltaic.[7] At the same

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time, consumers increasingly recognized in remote areas of photovoltaic products, more and more residents began using home solar power products.[8] The development of photovoltaic market rapid. However, there is a big gap between the China's solar photovoltaic technology and foreign countries. Therefore, China should continue to improve the technology so that China's solar photovoltaic industry could onto a new stage.

3. The Architecture of the Solar Photovoltaic Power Peneration System

The Solar photovoltaic power generation system is the use of photovoltaic modules semiconductor material "photovoltaic" effect.[2] It is new generation system that could convert the sun’s radiation to electricity. Its size is vary, and in the power generation process is no pollution. And it is easy installation, no noise. There is virtually no mantenance throughout the life. Solar photovoltaic System is divided into two categories, one is solar photovoltaic stand-alone systems, and the other is solar photovoltaic power generation and network systems. Solar photovoltaic stand-alone systems including solar modules, controllers, batteries, DC / AC inverter and so on. Its system structure is depicted in the figure 1.[12]

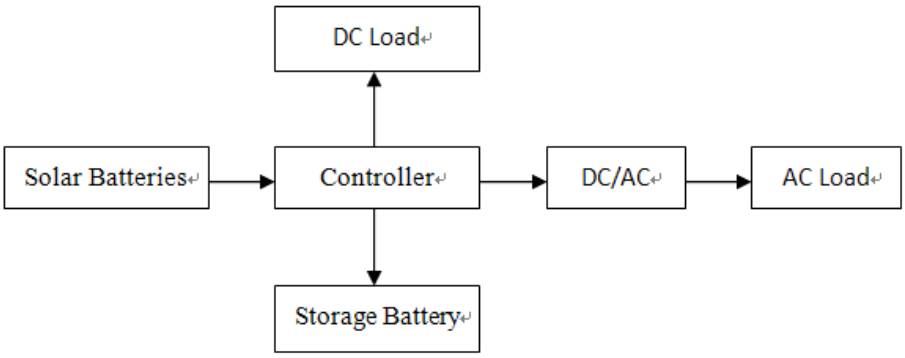

Figure 1. Photovoltaic Solar Power System Configuration Diagram

The present study design for the household solar photovoltaic power generation system is the independent power system, because the household solar photovoltaic system is generally established in the remote areas. Therefore, in the design process, the actual situation should be taken full account of . The principles of the economy applicable, reliability, durable, easy maintenance, geography and climate should be followed.

4. The Design of the Household Solar Power Generation System

Shenyang as an example in this article. Shenyang is located at longitude 123^{o}26’E, latitude 41^{o} 46’N, sea level is above 43 meters. According to calculate in Shenyang, the actual average time of sunshine is 7 huors. The time of the average peak sunshine is 4.56 hours. The time of the min average peak sunshine is 3.68 hours. According to the popular international received radiation PV system design standard, the best angle of the solar cell module is 51^{o}. The standard is that balanced in the seasons, the biggest in the weak quarter. In the requirements system, the battery storage capacity to meet the continuous in 3 rainy days. The depth of the battery discharge is 60%. The efficiency of power generation is 80%. Because the systems are used to provide power for the home, the battery system voltage is elected 48V for more safety.[14]

4.1 Electricity Demand

The solar photovoltaic power generation system needs to drive the load include: A LCD TV, its power is 250W, the average daily working time is 3 hours. A computer, its power is 2000W, the average daily working time is 3 hours. A induction cooker, its power is 2000W, the average daily working time is 0.5 hours. A refrigerator its power is 150W, the average daily working time is 6 hours. A microwave oven, its power is 1000W, the average daily working time is 0.5 hours. In order to facilitate computing, all the other electrical appliances imputed to 1000W, the average daily working time is 0.5 hours.

4.2 Ascertaining Standard of the Inverter

In the 4.1, based on the house load conditions, all the power of the load may also work together, adding calculation all the power, the conclusion of the household appliance is taken as the maximum load is approximately 5000W. According to the load capacity, this amount can be determined of the standard of the inverter. In the real Engineering, the load total power is greater than 80% of the total power of the inverter, the inverter will excessive heat, the life of the inverter will reduce. Therefore, when choice the inverter, the inverter loss rate need to be considered. In this paper, the coefficient is 1.2-1.5. The power of the inverter calculation is as follows:

$$P_{inverters}=5000\times1.2=6000\text{W}$$

According to calculated the inverter power is 6000W. Therefore, the inverter is 6000W. According to the actual status of the market price situation. An inverter is selected by this design, its price is 11000yuan.

4.3 Ascertaining the Capacity of the Battery

The capacity of the battery system is based on daily consumption volume, the number of consecutive rainy days, and to determine the depth of battery discharge. The specific formula is:

$$C=\frac{L\times D}{DOD\times E_1\times(1-E_2)}$$

In this formula: L: The system electricity consumption daily, unit is kW·h;

D: The maximum number of days of continuous rain;

DOD: The maximum depth of discharge of the battery;

E_1: System energy conversion rate(80%-90%);

E_2: Wire transmission losses(5%);

According to the formula: C=25kW·h.

This system supply power for home, from a security point of view, the voltage of battery is ascertained 48V, If the 12V lead-acid battery is choose as monomer, series into a 48V battery battery pack. According to the battery capacity formula:

$$Q=\frac{Q_1}{U}$$

In this formula: Q: Battery capacity;

Q_1: Consumption of system power;

U : Battery voltage;

According to the formula: Q =520A·h.

The battery capacity is 520A·h. If the battery is 200A·h/12V, then the connection is composed of a string of four batteries, a total of 3 series. So the actual capacity of the battery is 600A·h. According to the actual status of the market price situation. A battery is selected by this design, their price is 5000 yuan.

4.4 Ascertaining Solar Energy Cell Array

The solar cell module is the basis for solar power systems work. Its function is transforming the solar radiation into electrical energy. Its photoelectric conversion efficiency determines the efficiency of the power supply system. Therefore, the photoelectric conversion efficiency of the solar cell module as an important parameter to considert. Currently, solar cells are divided into monocry silicon, polycrystalline silicon and amorphous silicon. Photoelectric conversion rate of the one single crystalline silicon is 15%-20%, the most is to 24%. The life of using is about 15 years, the most is to 25 years. Photoelectric conversion rate of the polycrystalline silicon is 12%, amorphous silicon is 10%. This system use the single crystal silicon solar cells as the solar cell module.

The system electricity consumption daily is 25kW·h. According to the local average peak sunshine hours can be drawn Solar panel power is:

$$P_s = \frac{L}{T \times A_1 \times A_2}$$

In this formula: L : The system electricity consumption daily, unit is kW·h;

P_S : The total power of solar panels;

T : The peak sunshine hours;

A_1 : The Installed efficiency of inverter;

A_2 : The Installed efficiency of controller;

According to the formula: P_S =5500W. The system selects the peak power of 200Wp monocrystalline silicon solar panels 200Wp.The connection of solar panels for every two panels in series, then parallel access controller. According to the actual status of the market price situation. The solar panels are selected by this design, its price is 20000 yuan.They are from the company of YingLi.

4.5 Ascertaining Controller

Since the total power of the solar panels is 5500W, the voltage of system is 48V, the value of current could be ascertain:

$$I = \frac{P_s}{U}$$

According to the formula: I =115A. According to this calculation, the parameters of the controller can be obtained. (48V/120A) According to the actual status of the market price situation. A controller is selected by this design, its price is 3000 yuan.

4.6 Ascertaining the Angle of Installation of the Solar Energy Cell Array

Since the the angle of the sun light shines on the ground is changing all the time. when the sun light the solar cell in direc, the power generation efficiency is the highest. Therefore, square solar cells are arranged in two ways: one is to install the sun tracking system, another is according to the calculation to determine the optimum installation angle installation of solar cell matrix. The former can improve the power generation efficiency of the solar cell, but the high cost. The latter without the former high efficiency, but it has a lower construction costs. This design adopt the 2 type way.

Shenyang is located at longitude 123°26'E, latitude 41°46'N, the tropic of cancer is 23.45°, it is not close to the tropic of cancer. Lighting conditions are not very rich. Through the relevant meteorological data and formulas to calculate the optimum angle, the best angle of installation of the solar energy cell array is 51° in shenyang.

4.7 The Design of the Systems of the Lightning Protection

The grounding protection system is essential for any power system. Each part of the whole photovoltaic system has ground wire connection. After the battery plate and bracket fix well, solar panels connected to the metal frame bracket. Bracket use ground wire connected to the main ground line. Followed by the ground controller, inverter grounding wire should be connected to each other and the main ground line. In order to ensure safety.

4.8 The Stability Assessment of the PV System

As a role in the solar cell matrix based on the load, the first consideration is the wind pressure load. To consider the wind is strong, collapse, run by wind and other consequences, according to the actual local situation analysis and calculation on the basis of the stability of the solar cell phalanx. The weight of the scaffold can be used to repress according to the actual situation.

By matching and calculation of the various components of the system parameters, we can clearly understand the The design process. Since the purpose of this paper is about the PV system design process, so the system parameters during the configuration process for a number of approximate calculation, so that the final result will be some errors, in this as a special instruction. The wiring diagram of system is depicted in the Figure 2:

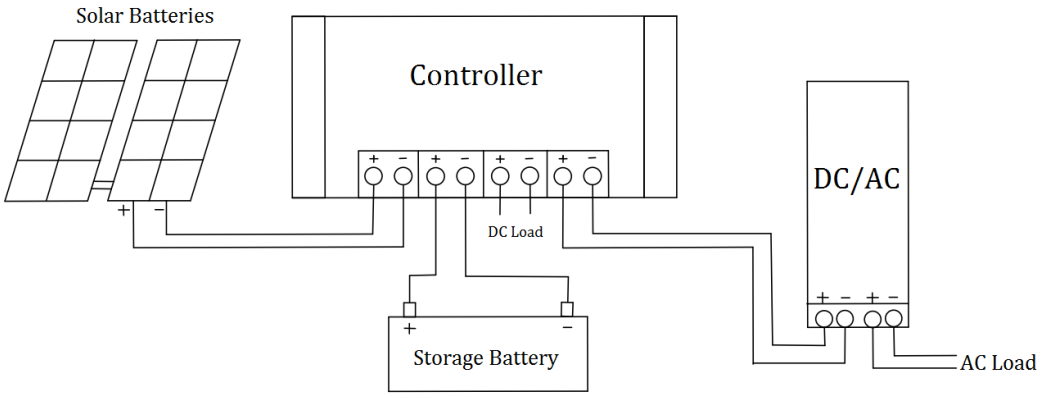

Figure 2. Photovoltaic Solar Power System Wiring Diagram

5. The Economic Evaluation of Household Solar Power Generation System

For the establishment of a photovoltaic power generation system, not only to pay attention to their build system, after setting up the system, the economic benefits, he system status, economic recovery period, which is the critical for the the System. There are following three aspects of the system from the PR of the indicators, Net Present Value(NPV) and Discounted Payback Period to analysis this system.

5.1 The Indicators of PR of the PV System

(1)The main factors affecting the generating capacity[1-6]

The total efficiency of the photovoltaic power generation system consists of the efficiency of the inverter, the efficiency of the PV array, the efficiency of the AC grid-connected and the decay of the system capacity.

The efficiency of the PV array is DC output power of the PV array and the actual power ratio.From the energy conversion and transmission over cause the loss process impacts include: components match loss, loss of surface dust obscured the sun cannot take advantage of the radiation loss, temperature effects and the DC line losses.

The efficiency of the inverter is the ratio of the output AC power and input DC power. Influence the efficiency losses of the inverter include: inverter AC-DC converter of energy loss caused by the maximum power point tracking (MPPT) precision losses.

The efficiency of the AC grid-connected included the efficiency of the inverter to the high voltage grid. The main loss of the transmission are the loss of the step-up transformer and the loss of the AC electrical connections.

Crystalline silicon PV modules output power attenuation caused by the use of the light and conventional atmosphere. In the case of PV power plant normal operation, the main factors affecting the PV power plant generating capacity of PV modules surface dust obscured the sun radiation losses.

(2)The principle of photovoltaic system efficiency testing[11-13]

Overall power generation efficiency formula is:

$$PR = \frac{PDR}{PT}$$

In this formula: PDR: The value of the actual power generation test time interval;

PT: The value of the theory power generation test time interval;

In the value of the theory generation PT formula:

$$T = \frac{I_i}{I_0}$$

The time of the PV power plant within the test interval time corresponds to the actual effective power under STC condition.

In this formula: P : Components nominal capacity of photovoltaic power plants under

STC conditions;

I_0 : The total value of the solar radiation conditions under STC

I_0 =1000W/m^2;

I_i : The total value of solar radiation test of time;

5.2 The Net Present Value of the PV system

In the project calculation period, the present value of net cash flow for each year according to industry benchmark discount rate or discount rate set by other calculations of sum algebra. Net present value is defined as the net cash flow generated by the investment program in order to fund the cost of the original investment after the discount rate discount the difference between the present value of the amount. NPV is the net present value to evaluate the size of the merits of a method scheme. NPV is greater than zero is feasible, and the greater the NPV, the more gifted program, better investment returns. The formulais:

$$NPV = -C_0 + (B-C) \times \left[\frac{(1+i)^n - 1}{(1+i)^n \times i} \right] - \frac{B_{cost}}{(1+i)^{n_b}} - \frac{C_{cost}}{(1+i)^{n_c}} - \cdots\cdots$$

In this formula: C_0 : The initial investment of solar power systems;

B : The generation system of annual revenue;

C : Operating costs of photovoltaic power generation system;

n : PV system life (25 years);

B_{cost} : The costs of battery replacement;

n_b : The time of battery replacement(10 years);

C_{cost} : The costs of controller replacement;

n_c : The time of controller replacemen(15 years);

i : Renewable energy systems of social APR(10%);

Adding the prices of inverter, storage battery, Solar Energy Cell and controller, the prices are 38000 yuan. The other costs are 12000 yuan. They including the prices of the costs construction, the cable,and so on.So the prices are 40000 yuan.

According to the formula:

$$NPV = -40000 + (5000-0) \times \left[\frac{(1+0.1)^{25}}{(1+0.1)^{25} \times 0.1} \right] - \frac{5000}{(1+0.1)^9} - \frac{5000}{(1+0.1)^{19}} - \frac{3000}{(1+0.1)^{15}}$$

NPV =6920yuan

NVP is the economic significance when NPV>0 indicates that the project implementation, in addition to ensure a predetermined rate of return can be achieved, and can still get higher returns. NPV <0 indicates that the project implementation, failed to achieve the desired yield level, and cannot determine the project has been a loss. Investment rate of return NPV = 0 indicates the project after just meet expectations, rather than the profit and loss balance of investment projects.

This systems can get higher returns this system, it can be invested.

5.3 The Discounted Payback Period of the PV system

In addition to the advantages of photovoltaic power generation system using clean energy, and to protect the environment, the second biggest advantage is that you can create income. Initially only be done once the initial investment has been recovered to the cost in PV system life cycle. During the period, people are income. But the key question is how to design a more optimized power system, making the cost to a minimum, in the shortest possible time to recover costs. In the calculation of the payback period of the calculation process, taking into account social APR, currency depreciation, maintenance of equipment and the maintenance period, so this is a very complex calculation process.

Principle of dynamic investment recovery period is:

$$n_{dp} = \frac{\ln(B-C) - \ln[(B-C) - i \times C_0]}{\ln(1+i)}$$

According to the formula:

$$n_{dp} = \frac{\ln(5000-0) - \ln[(5000-0) - 0.1 \times 40000]}{\ln(1+0.1)}$$

n_{dp}=13.4years.This calculation results show that the assumptions in accordance with article, after 13.4 years person can recover the cost of this project, and after 25 years to recover the cost will create revenue.

With the development of technology, the cost of photovoltaic industry is also gradually reducing. Now the cost of photovoltaic systems assembly is 7-8 yuan / watt, and this is just an upper limit. When one day, the cost of the photovoltaic industry can further reduce the future economic benefits of photovoltaic power generation will become better.

6. Conclusion

This paper introduces the design method of household photovoltaic power generation system and the economy after the design of the system is analyzed. Calculated the net present value and dynamic payback period of the system. The final results show that the household can invest in photovoltaic power generation projects, and has good profitability.

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Authors

Tieyan Zhang was born in 1962. He received the Ph. D. degree in control theory and control engineering from Northeastern University, Shenyang, China, in 2007. He is currently a professor of Shenyang University of Technology, Shenyang. His current research interests include fuzzy controls, fault diagnosis on electric power systems, and stability analysis on smart grids.

Peng Liu received the B. E. degree in Automation from Shenyang Institute of Engineering, Liaoning, China in 2013. He is currently working towards the Master in Electrical Engineering in Shenyang Institute of Engineering.

Zhenhe Ju was born in 1962. He graduated from Nankai University master of the world economy in July 1999, and received a master's degree in Sweden Dalarna University/European Solar Engineering Solar Energy Research Center in July 2003. He is currently a professor of the Shenyang Institute of Engineering, Shenyang. And he is a director and chief engineer of Liaoning Solar Energy R&D CO. LTD. He is an expert that enjoy the State Council special allowances.