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Escuela Técnica Superior de Ingeniería Industrial

UNIVERSIDAD POLITÉCNICA DE CARTAGENA

Escuela Técnica Superior de Ingeniería Industrial

Hami Tianshan build solar energy storage project.

TRABAJO FIN DE MÁSTER

MÁSTER UNIVERSITARIO EN ENERGÍAS RENOVABLES

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Abstract

This master thesis consists of two parts and an additional part. in the first part, we analyze the geographical and climatic conditions of the project area. design the most suitable photovoltaic power generation and the required photovoltaic power generation equipment. In the second part, we calculate the required battery according to the data in the previous part. then analyze the function of the battery to select the most suitable battery. additional parts to design battery room and heating measures for protecting batteries and other power generation equipment.

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Introduction

The world's energy problems are mainly reflected in the energy crisis caused by energy shortages and supply and demand conflicts. Another challenge facing the world's energy is that with the development of the economy and the improvement of living standards, people's requirements for environmental quality are getting higher and higher, and the corresponding environmental protection standards and environmental protection regulations are becoming more and more strict. Therefore, a new type of energy has been discovered.

One of them is photovoltaic energy. Photovoltaic energy comes from the sun, and the sun is a huge, long-lasting, endless source of energy. Although the sun's radiation to the Earth's atmosphere is only one-billionth of its total radiant energy (about 3.75 × l026 W), it is as high as 1.73 × 1017 W. In other words, and the sun radiates to earth every second. The energy is equivalent to 5 million tons of coal.

Solar energy is an inexhaustible source of energy. The use of solar energy does not emit toxic pollutants, which is beneficial to the protection of human living conditions and sustainable development.

To get low investment and clean energy, we design the solar energy system and storage field in Hami Tianshan district. Photovoltaics are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons by the Photovoltaic effect.

History of solar energy

Charles Fritts installed the world's first rooftop photovoltaic solar array, using 1%-efficient selenium cells, on a New York City roof in 1884. Humans began to research the replacement of raw fuel energy with solar energy. The 1973 oil embargo and 1979 energy crisis caused a reorganization of energy policies around the world and brought renewed attention to developing solar technologies. In the early 2000s, Solar technology has overgrown. In addition to Europe and the United States, many Asian countries and other regions Joined this research and building solar energy. [1]

Technology of solar panels

The central part of converting light energy into electricity here is solar panels. Technical process: Slicing, cleaning, preparing suede, peripheral etching, removing the back PN+ junction, making the upper and lower electrodes, making an anti-reflection film, sintering, testing the split, etc. 10 steps.

(1)Slicing: Using a multi-wire cut, the silicon rod is cut into square wafers.

(2) Cleaning: It is cleaned by a conventional wafer cleaning method, and then the surface of the silicon wafer is cut with an acid (or alkali) solution to remove the damaged layer by 30-50 um.

(3) Preparation of suede: anisotropic etching of the silicon wafer with an alkali solution the suede was prepared on the surface of the silicon wafer.

(4) Phosphorus diffusion: The coating source (or liquid source, or solid phosphorus nitride sheet source) is used for diffusion to form a PN+ junction, and the junction depth is generally 0.3-0.5 um.

(5) Peripheral etching: A diffusion layer formed on the peripheral surface of the silicon wafer during diffusion causes short-circuiting of the upper and lower electrodes of the battery, and the peripheral diffusion layer is removed by masking wet etching or plasma dry etching.

(6) Remove the back PN+ junction. The back side PN+ junction is removed by conventional wet etching or grinding.

(7) Making upper and lower electrodes: using vacuum evaporation, electroless nickel plating or aluminum paste printing and sintering. Make the lower electrode first, then make the upper electrode. Aluminum paste printing is a widely used process.

(8) Making an anti-reflection film: To reduce the reflection loss, an anti-reflection film is coated on the surface of the silicon wafer. The materials for making the

anti-reflection film are MgF_2, SiO_2, Al_2O_3, SiO, Si_3N_4, TiO_2, Ta_2O_5 and the like. The method may be a vacuum coating method, an ion plating method, a sputtering method, a printing method, a PECVD method, or a spray method.

(9) Sintering: the battery chip is sintered on a base plate of nickel or copper.

(10) Test binning: test classification according to the detailed parameter specifications.

material classification

At present, crystalline silicon materials (including polycrystalline silicon and monocrystalline silicon) are the essential photovoltaic materials, and their market share is over 90%, and it is still the mainstream material for solar cells for an extended period in the future.

And other material

Crystalline silicon panels: poly crystalline silicon solar cells, mono crystalline silicon solar cells.

Amorphous silicon panels: thin film solar cells, organic solar cells.

Chemical dye panel: Dye-sensitized solar cell.

Flexible solar cell.

Same models

Poly crystalline silicon solar cells

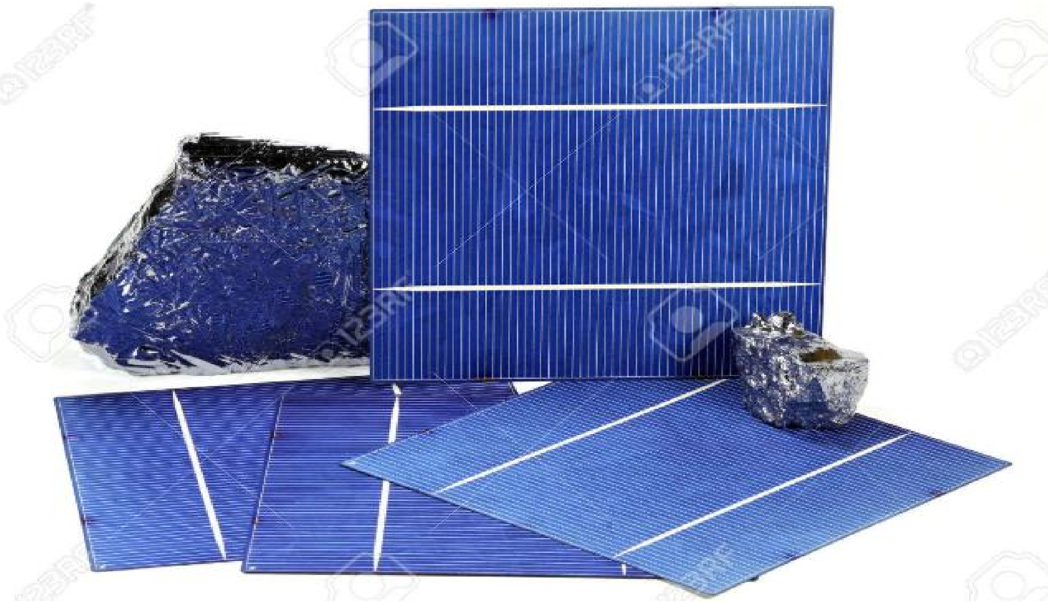


Fig.1[2]

Mono crystalline silicon solar cells

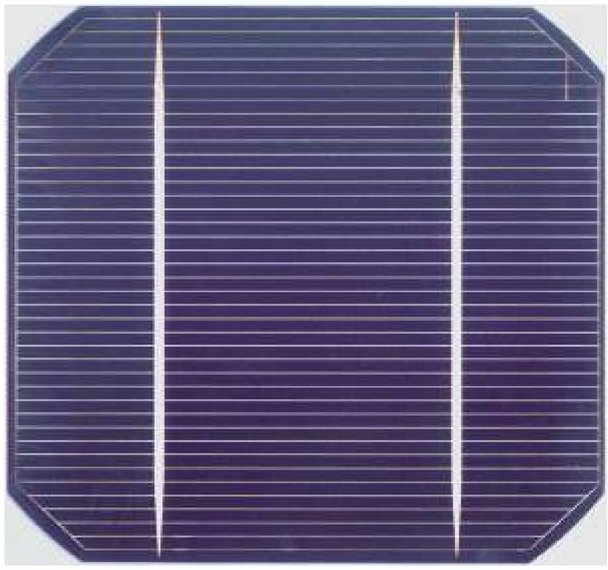


Fig2[3]

thin film solar cells

Fig.3[4]

organic solar cells

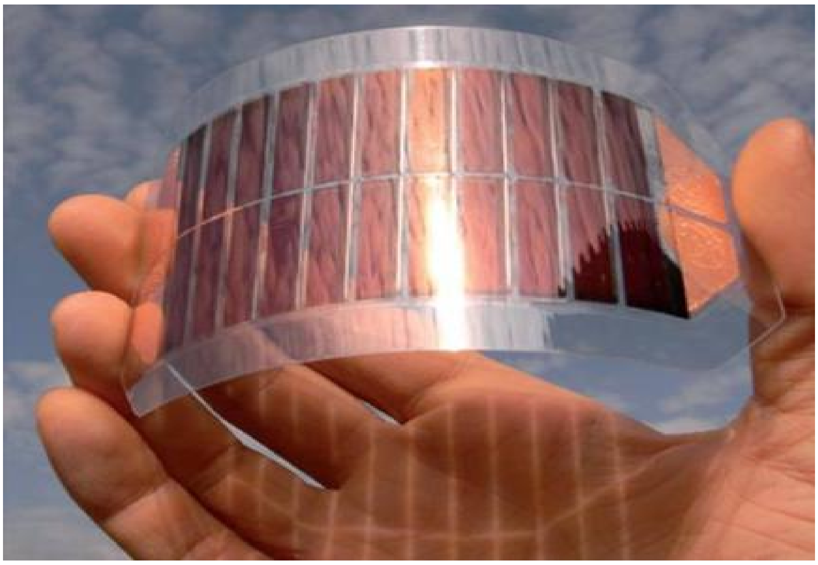


Fig.4[5]

Dye-sensitized solar cell

Fig.5[6]

Flexible solar cell

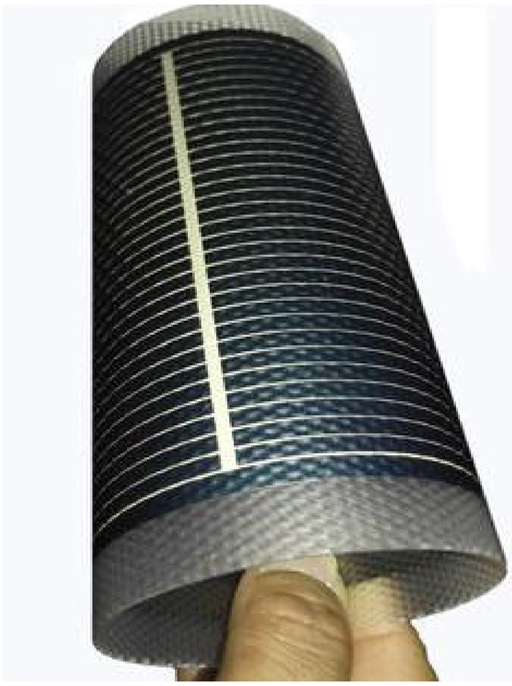


Fig.6[7]

Solar energy Capacity in the world

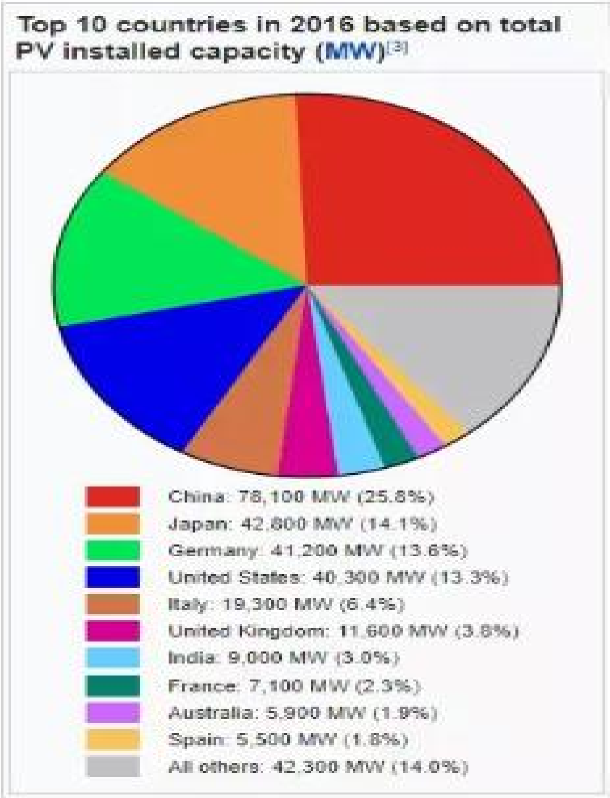


Fig.7[8]

Solar power in china

China is the world's largest market for both photovoltaics and solar thermal energy. Since 2013 China has been the world's leading installer of solar photovoltaics (PV). In 2015, China became the world's largest producer of photovoltaic power, narrowly surpassing Germany.

In China in 2017 electricity produced 6412 Gwh, 118.2Gwh was generated by solar power equivalent to 1.84% of total electricity production.[9]

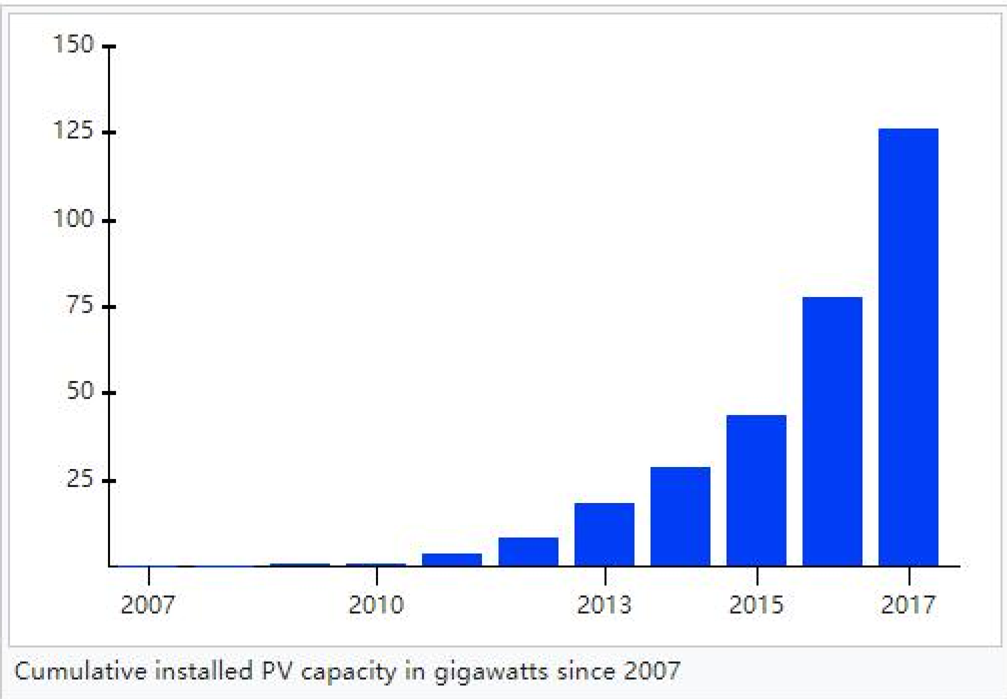


Fig.8Solar PV by province[10]

A large part of the solar power capacity installed in China is in form of large PV power plants in the west part of the country, much less populated than the eastern part but with better solar resources and available land.

Tab .1 top ten province Installed solar PV capacity in china

province	MW end of 2015	MW end of 2016	Population (thousands)	Watts per capita
China total	43,170	77,420	1,339,725	58
Xinjiang	4,060	8,620	21,813	395
Gansu	6,100	6,860	25,575	268
Qinghai	5,640	6,820	5,627	1,212
Inner Mongolia	4,880	6,370	24,706	258
Jiangsu	4,220	5,460	78,660	69
Ningxia	3,080	5,260	6,177	852
Shandong	1,330	4,450	95,793	46
Hebei	2,390	4,430	71,854	62
Anhui	1,210	3,450	59,501	58
Zhejiang	1,640	3,380	54,427	62

Due to the rotation of the earth, solar energy is intermittent. That is to say, for the same place, it can receive. Solar power is intermittent. This determines: or solar energy can only be used as an auxiliary energy source, or it is necessary to increase the energy storage device.

In addition to space power plants, the application of other photovoltaic power generation systems is affected by daylight and five days of nighttime illumination. So for its load, it may have to run both day and night. For this type of load, the battery is mainly used as an energy storage unit in the whole system.

Battery

The battery is a device consisting of one or more electrochemical cells with external connections provided to electrical power devices such as flashlights, smartphones, and electric cars.

History of battery

Historically, the word “battery” was used to describe a “series of similar objects grouped to perform a function,” as in a battery of artillery. In 1749, Benjamin Franklin first used the term to describe a series of capacitors he had linked together for his electricity experiments. Later, the time would be used for any electrochemical cells connected to electric power.

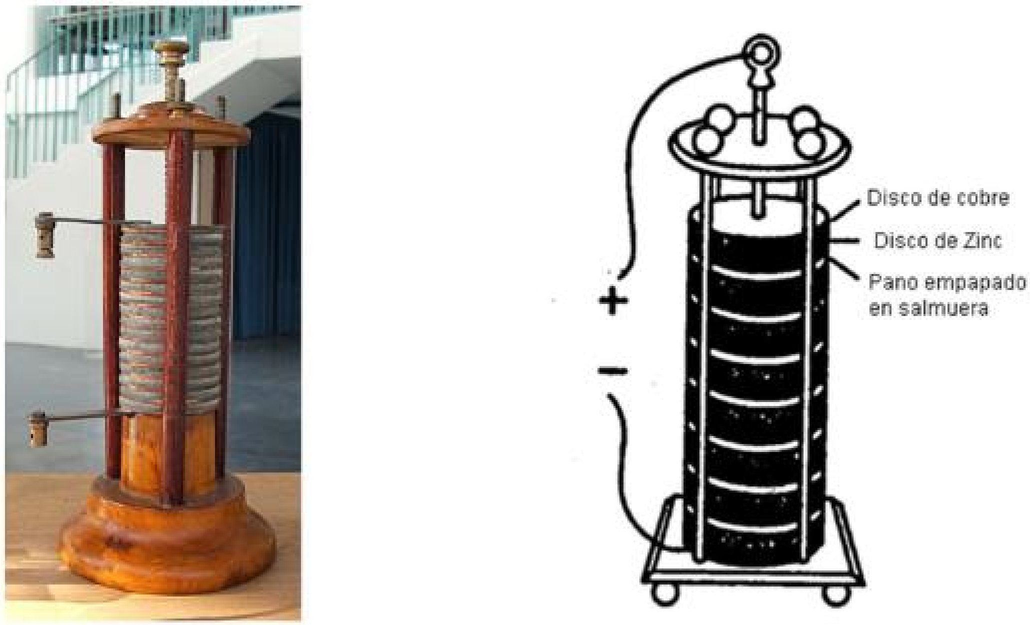


Fig.9[11]

Invention of the Battery

One fateful day in 1780, Italian physicist, physician, biologist, and philosopher, Luigi Galvani, was dissecting a frog attached to a brass hook. As he touched the frog’s leg with an iron staple, the leg twitched. Galvani theorized that the energy came from the pin itself, but his fellow scientist, Alessandro Volta, believed otherwise.

Volta hypothesized that different metals soaked in a liquid caused the frog's leg impulses. He repeated the experiment using a cloth soaked in brine instead of a frog corpse, which resulted in a similar voltage. Volta published his findings in 1791 and later created the first battery, the voltaic pile, in 1800.[12]

Components

Batteries are made up of three basic components: an anode, a cathode, and an electrolyte.

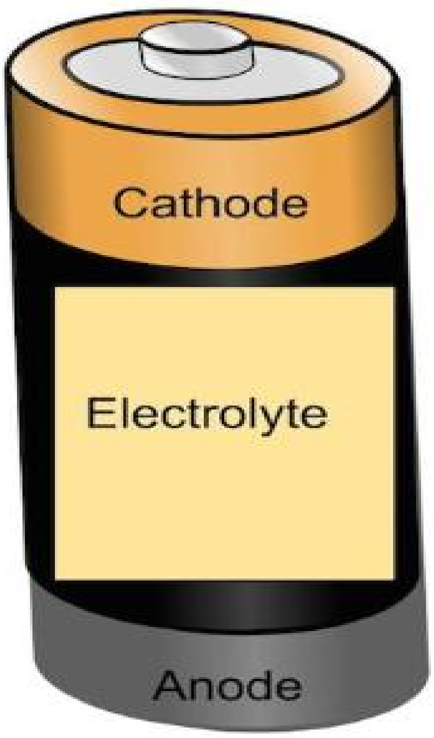


Fig.10[13]

Type of battery

Primary cells or non-rechargeable batteries

Aluminum–air battery, Atomic battery, Betavoltaics, Optoelectric nuclear battery, Nuclear micro-battery, Bunsen cell, Chromic acid cell (Poggendorff cell), Clark cell, Daniell cell, Dry cell, Earth battery, Frog battery, Galvanic cell.

Secondary cells or rechargeable batteries

Aluminum-ion battery, Flow battery, Vanadium redox battery, Zinc-bromine battery, Zinc–cerium battery, Lead–acid battery, Deep cycle battery.

Target battery

That photovoltaic system continuously supplies universal energy. The battery type we can choose is a rechargeable battery. A rechargeable battery, storage battery, secondary cell, or accumulator is a type of electrical battery which can be charged, discharged into a load, and recharged many times, as opposed to a disposable or primary battery, which is supplied fully charged and discarded after use. It is composed of one or more electrochemical cells. The term "accumulator" is used as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–

acid, nickel–cadmium (NiCd), nickel–metal hydride (NiMH), lithium-ion (Li-ion), and lithium-ion polymer (Li-ion polymer).

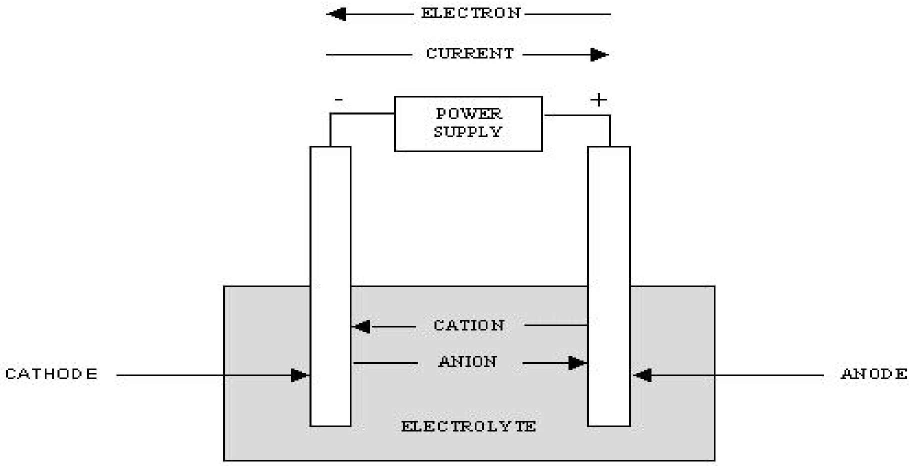


Fig. 11[14]

Type of the target batteries

Lead-acid batteries

Construction

Lead-acid batteries consist of plates (electrodes), separators and electrolyte. In the charged state a negative electrode material comprises of spongy lead (Pb) with antimony, because of better mechanical characteristic. The positive electrode is made from lead oxide (PbO_2). Plates are in the form of rectangular grids. The space between the network is filled with electrolyte which consists of 33-35% dilute sulphuric acid. Between positive and negative plates are separators preventing a short-circuit between physical contact Spacers avoid the movement of ions and increase the resistance of cells, and they are usually made of wood, rubber, glass, cellulose, PVC or polyethylene plastic.

Specification of lead-acid battery

Energy density	50 - 80 [Wh/dm3]
Specific energy	30 - 50 [Wh/kg]
Specific power	180 [W/kg]
Charge/discharge efficiency	50-90 [%]
Self discharge rate	3-20 [%/month]
Lifetime	500 - 1000 [cycles]

Construction of Lead-acid batter

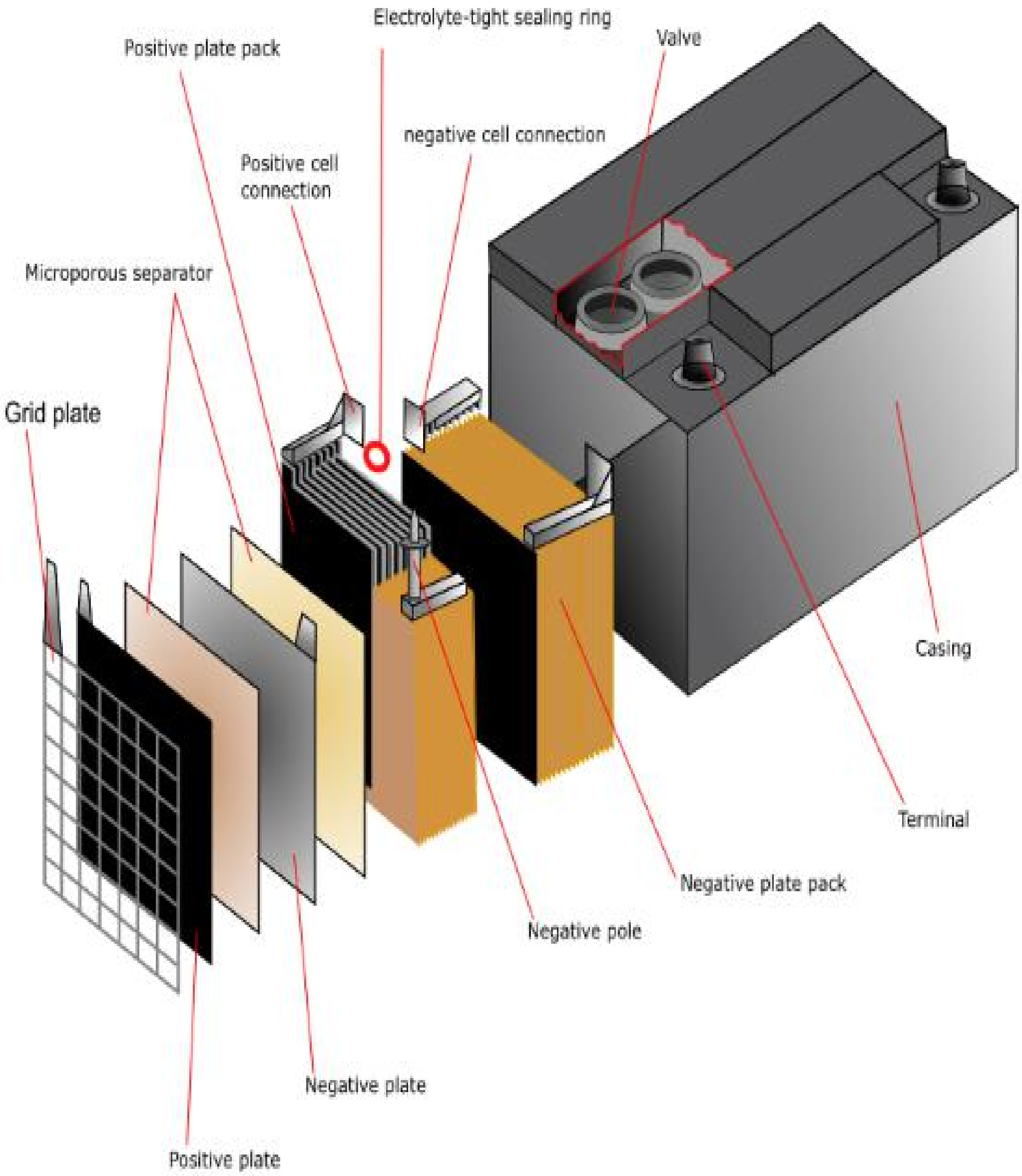


Fig. 12[15]

Chemical reactions of lead-acid batteries on electrodes during the cycles:

Charging

Negative plate reaction: PbSO4(s) + H+(aq) + 2-e → Pb(s) + HSO− (aq)

Positive plate reaction: PbSO4(s) + 2H2O(l) → PbO2(s) + HSO− (aq) + 3H+(aq) + 2-e

Discharging

Negative electrode reaction: $Pb(s) + HSO_4^- (aq) \rightarrow PbSO_4 (s) + H^+(aq) + 2e^-$

Positive electrode reaction: $PbO_2(s) + HSO_4^- (aq) + 3H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Advantages

Low cost.

Robust. Tolerant of abuse.

Tolerant of overcharging.

Low internal impedance.

Can deliver very high currents.

Indefinite shelf life if stored without electrolyte.

Can be left on trickle or float charge for prolonged periods.

A wide range of sizes and capacities available.

Many suppliers worldwide.

Disadvantages

low specific energy and energy density

self-discharging

Very heavy and bulky.

Typical coulombic charge efficiency only 70% but can be as high as 85% to 90% for special designs.

The danger of overheating during charging

Not suitable for fast charging

Typical cycle life 300 to 500 cycles.

Must be stored in a charged state once the electrolyte has been introduced to avoid deterioration of the active chemicals.

Parameters

Cycles life

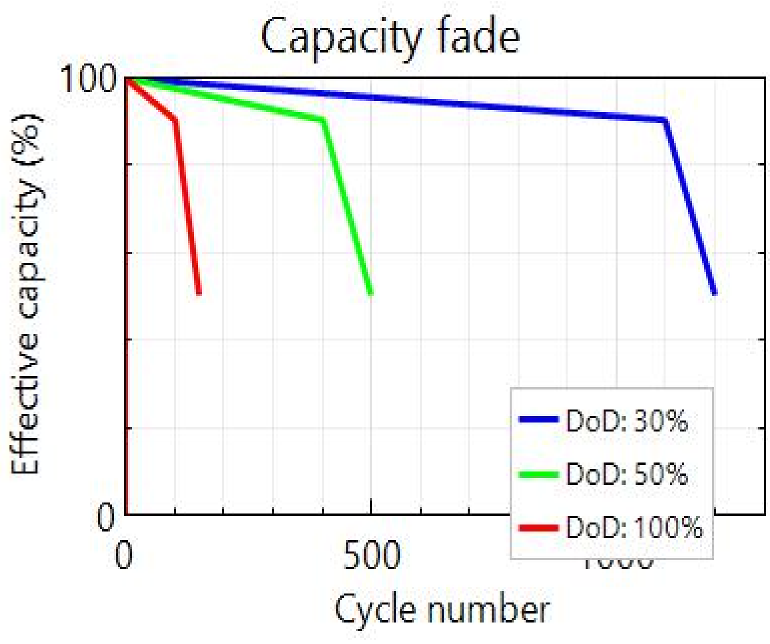


Fig13[16]

Lithium iron phosphate battery

The lithium iron phosphate ($LiFePO4$) battery, also called LFP battery (with "LFP" standing for "lithium iron phosphate"), is a type of rechargeable battery, specifically a lithium-ion battery, which uses $LiFePO4$ as a cathode material, and a graphitic carbon electrode with a metallic current collector grid as the anode.[17].

Technical specification

Nominal voltage	3.3 V nominal
End-of-charge voltage	3.65 V
Energy density	90 – 120 Wh/Kg
Charging rate (C-rate)	Typically 0.5 – 2 C
Discharge rate (C-rate)	0.2 C – 5 C
No. of cycles	300 – 2000
Temperature range	-20°C ~ +60°C
Self-discharge	~ 3% / per month

Tab.2[18]

Construction lithium iron phosphate battery

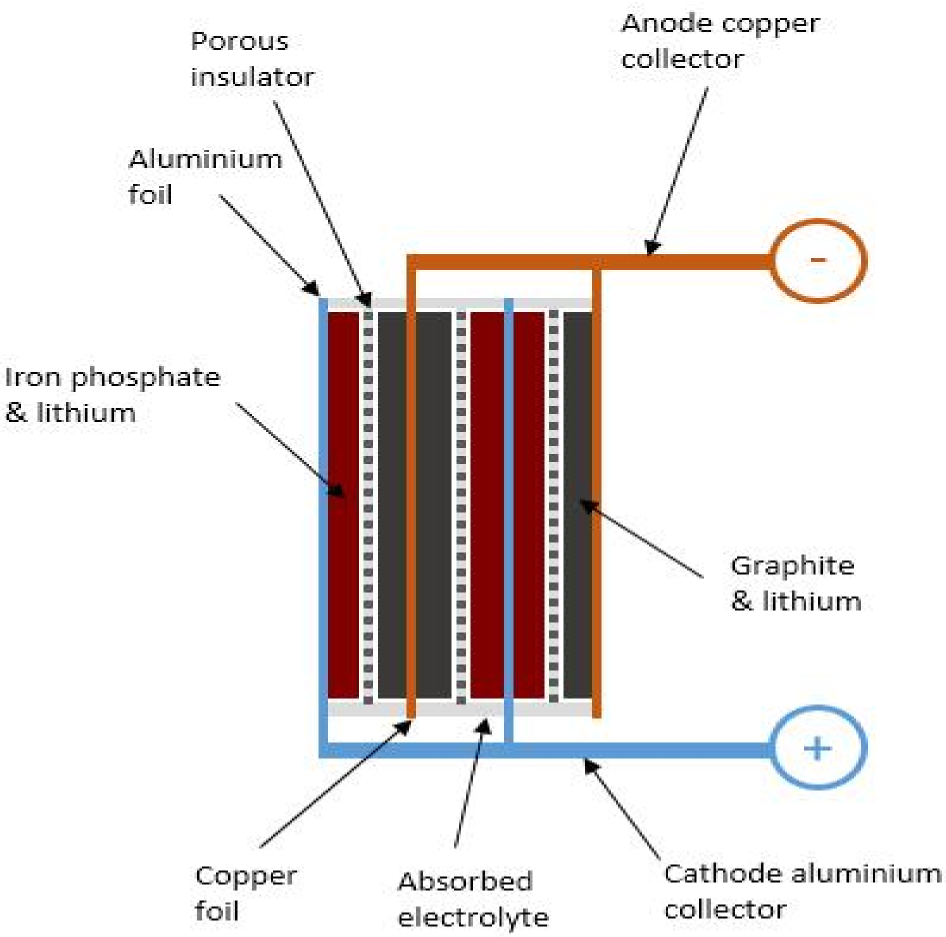


Fig. 14[19]

Lithium iron phosphate two part reaction

$LiFePO_4$ ←→ $FePO_4$ + Li^{+}+e-

(positive electrode):cathode

Lithium iron phosphate on

Aluminum terminal

Electrolyte:LiPF6 in ethylene carbonate(EC)/dimethyl carbonate(DMC)

Li+ + e- + C ←→ LiC6

(negative electrode):Anode

Graphite on copper terminal

Left to right = charging Right to Left = Discharging

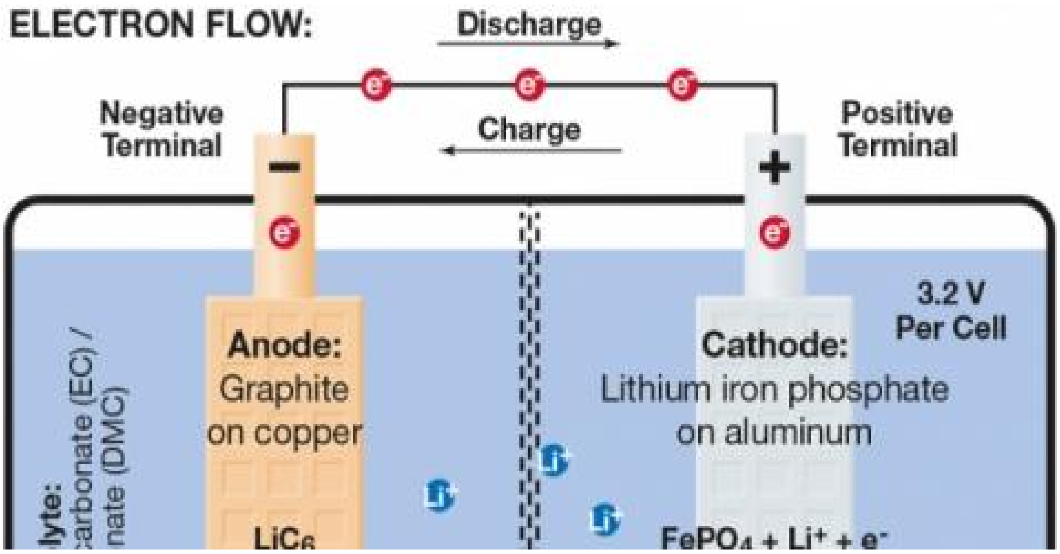


Fig.15[20]

Advantages

cycle life longer.

have a very constant discharge voltage.

Good temperature performance.

High capacity [it has a larger capacity than ordinary batteries (lead-acid, etc.).

5AH-1000AH (single)].

No memory effect.

Lightweight.

Environmental protection.

Disadvantage
Low energy density

Has a low discharge rate

Material preparation cost and battery manufacturing cost are higher

Poor product consistency

Parameter

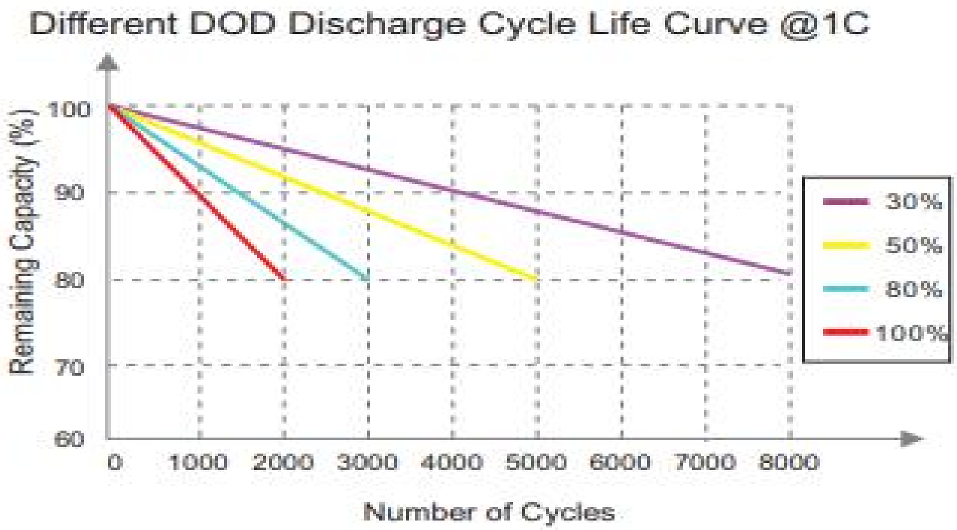


fig.16[21]

Colloidal battery

A battery is provided having cells, which cells contain an electrolyte and a colloid, with there being at least one connector between directly adjacent cells, with each cell being formed of at least one pair of component sections, with each of the component sections in the pair being separated by a filter. the filter has apertures formed therein. the filter has two sides with a channel formed connecting apertures on opposite sides of the filter. When the battery discharges, the battery will flush the filter.

Specification of colloidal battery

Nominal voltage 2v

capacity retention rate : ≥ 98%(month)

Float design life :7-10(40Ah or more, year,25℃)

Discharge temperature : -15℃~+50℃

Self-discharge per month : ≤ 5%

N°cycle life: 50% ≥ 2000 times

Recharge time: 3-5h

Wide range of capabilities : (1.2Ah~200Ah)

Construction of colloidal battery

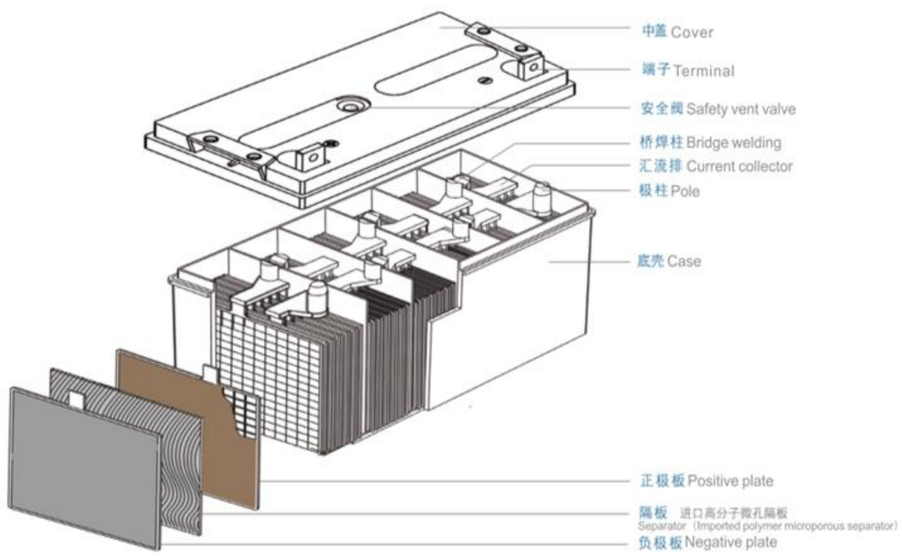


Fig. 17**[22]**

Reaction

The two half-reactions which would occur at such time as the battery is being discharged are as follows:

$PbO_2(s)+4H^+(aq)+SO_4^{2-}(aq)+2e^- \rightarrow PbSO_4(s)+2H_2O$ (cathode)

$Pb(s)+SO_4^{2-}(aq) \rightarrow PbSO_4(s)+2e^-$(anode),

such that the net reaction taking place in each cell is:

$PbO_2(s)+Pb(s)+2H_2SO_4 \rightarrow 2PbSO_4(s)+2H_2O$

Advantages

The colloidal battery has a large amount of acid

The internal resistance of the gel battery is larger

Heat is easy to spread, not easy to heat up

Safe to use and environmentally friendly

Adapt to the environment (temperature) -40℃~+65℃

has high Sulfur resistance

Has Strong recovery

Strong anti-overcharge

Good discharge performance

Disadvantages

Production technology is difficult and high costly

Cycle life is a little short

Heavier

Parameter

Cycle life [22]

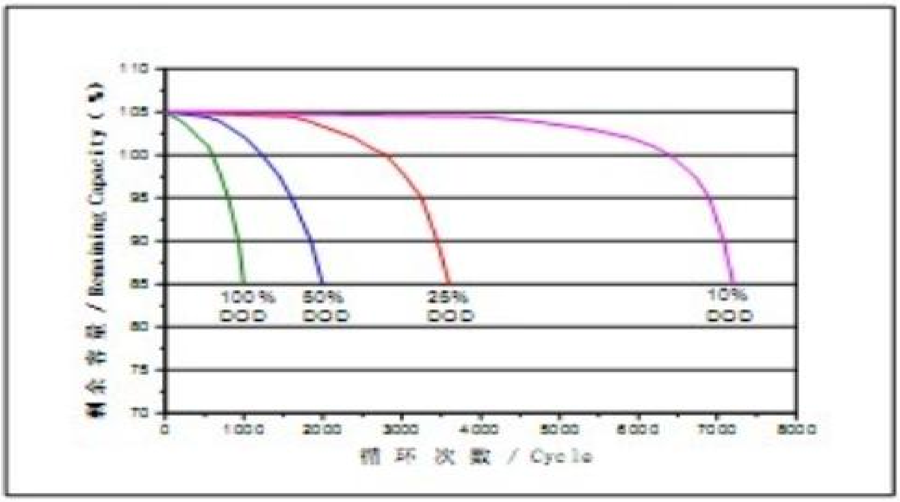


Fig.18

Energy storage application status

Global energy storage application status

Annual Energy Storage Deployments by Market, 2017 (MW and MWh)

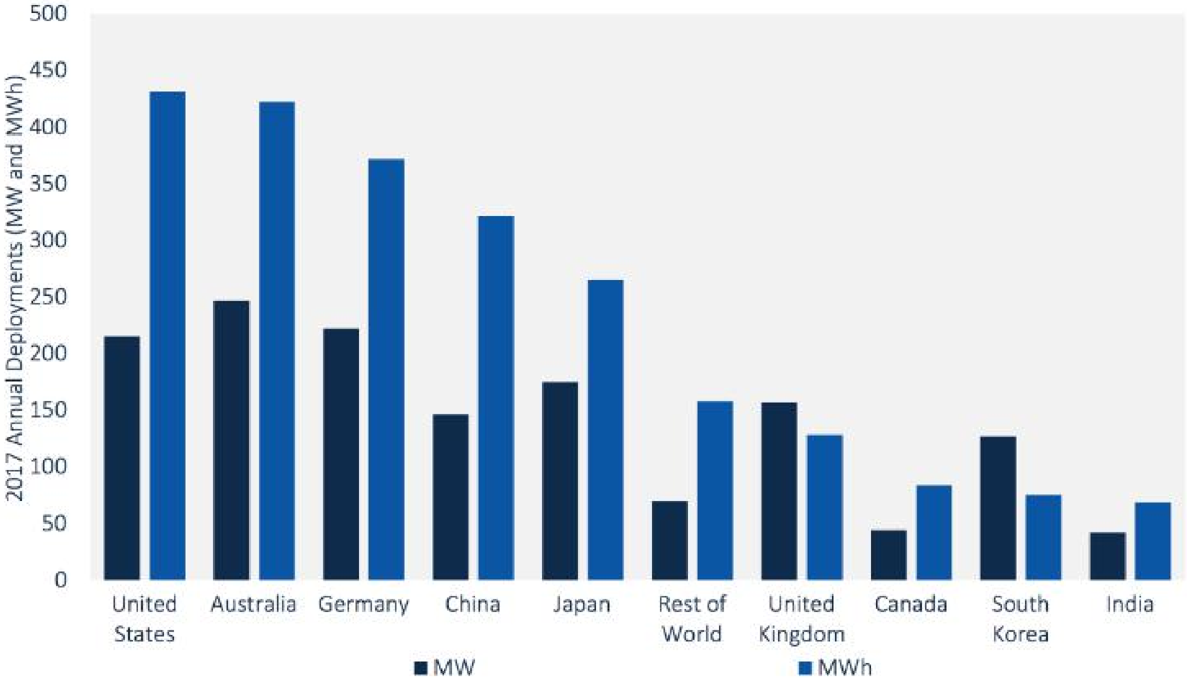


Fig.19[23]

Cumulative installation distribution of different types of energy storage on various applications globally

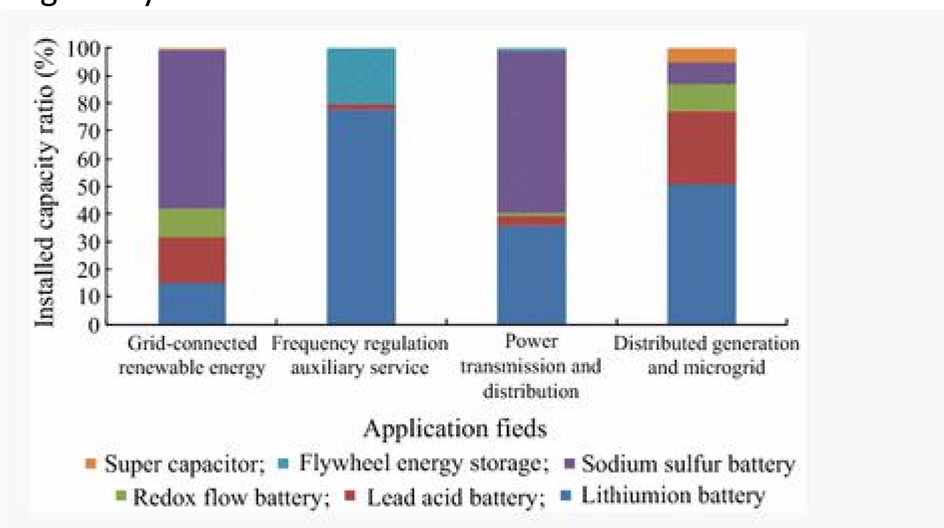
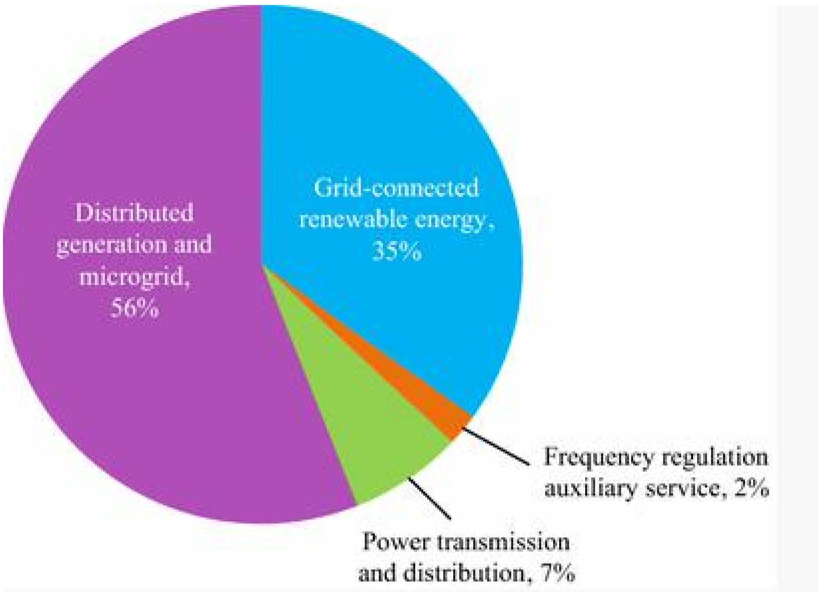


Fig.20[24]

Energy storage application in China

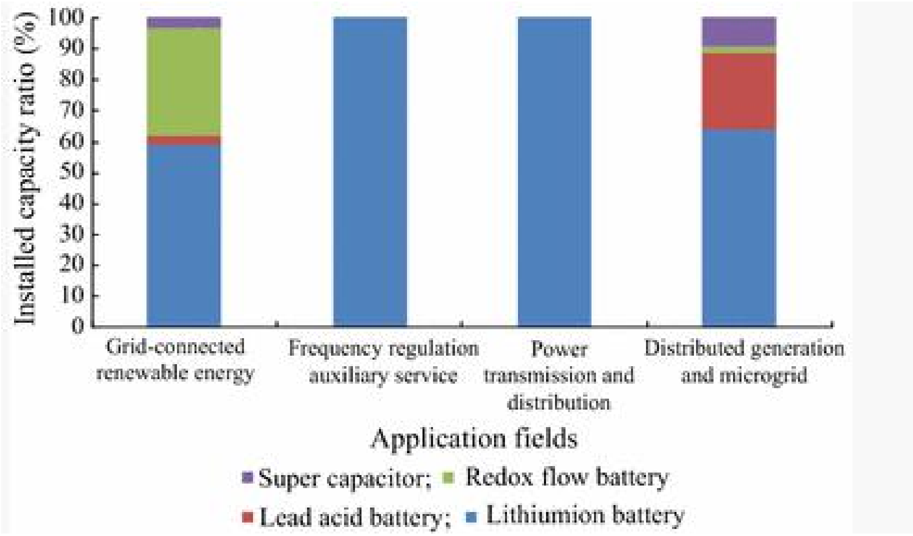
By the end of 2015, the cumulative installed energy storage capacity in China was 105.5MW, which is about 11% of global installed energy storage.

In terms of application, the installed capacity of energy storage in China is different from other countries, and energy storage applications in distributed generation and microgrid field account for 56%. Among them, lithium-ion batteries and lead-acid batteries are two of the most widely used technologies and reach up to 89% in total. Energy storage projects are mainly implemented in the island and remote areas, business areas, and electric vehicles.



Cumulative installation distribution of energy storage for various applications in China

Fig.21[25]



Cumulative installation distribution of different types of energy storage for various applications in China

Fig.22[26]

Current status and main problems of energy storage systems in project areas

The storage and management of electrical energy are essential in photovoltaic systems. At present, the energy storage device commonly used in photovoltaic power generation systems in the project area is a lead-acid battery. However, it has some insurmountable shortcomings such as short cycle life, low power density, and high maintenance, and the cost of the entire power generation system is high. That area the photovoltaic system installed by the villagers themselves are various types Power generation is shallow. Not yet entirely universal for every family, this is the problem we have to solve.below we want to analyze the actual energy needs there and design a suitable continuous power generation system.

Project Overview

This project is located in Hami, Xinjiang Fig.23[27]

Project Geographical location

The northernmost part of the area is in the Dahadaka Mountain in Santanghu Township, Kazakh Autonomous County, Bali, about 45 degrees 5 minutes and 33 seconds north latitude; the south is near Bailong Mountain in Nanhu Township, Hami City, about 40 degrees 52 minutes and 47 seconds north latitude; The most east is about 96 degrees 23 minutes east longitude of Xingxingxia, and the west is about 91 degrees 6 minutes 33 seconds east of Qijiao Well.[28]

Sunshine Hours

The annual sunshine hours in the Hami region range from 3 170 to 3 380 hours, which is one of the regions with ample sunshine hours in the country. Xing Xing Xia, located in the eastern part of the area, enjoys 3,500 hours of sunshine each year, 350 hours more than Li has, commonly known as “Sunlight City.” Hami, Santana Lake - Mang hu Basin Plain, with 3,350 hours of sunshine hours throughout the year. The Balikun Basin and Yiwu Valley in the Tianshan Mountains are 3 170 hours and 3 250 hours respectively.[29]

In this project, we use the Tian Shan to obtain sunshine hours.3 170 hours and 3 250 hours respectively.

Basic climate of the project site

Hami is a typical temperate continental arid climate with dry and dry weather, sunny days, annual average temperature 9.8 degrees, annual precipitation 33.8 mm, annual evaporation of 3,300 mm, the annual average of 3,358 hours, and a frost-free period of 182 days. The spring is windy, cold and warm, with intense summer heat and strong evaporation. The autumn is sunny, and the temperature is cool rapidly. The winter is cold, and the low air layer is stable. The extreme maximum heat is 43 ° C; the absolute minimum temperature is -32 ° C, and the frost-free period averages 182 days. The air is dry, the atmosphere is transparent, the cloud cover is less, and the light energy resources are abundant. It is one of the regions with excellent light energy resources in the country, and the sunshine is sufficient. The annual sunshine hours are 3300 to 3500 hours, which is the area with the most sunshine hours in the country.

Basic climate of Hami (according to 1971-2000data)												
Month	1	2	3	4	5	6	7	8	9	10	11	12
Average temperature (℃)	-10.4	-4.1	4.6	13.5	20.2	24.6	26.5	24.7	18.2	9.4	0.0	-8.0
Average maximum temperature(℃)	-3.1	3.7	12.3	21.5	28.0	32.2	34.2	33.2	27.6	18.7	7.5	-1.5
Extreme maximum temperature(℃)	7.8	14.2	25.9	34.0	38.8	39.6	43.2	42.6	37.5	31.7	20.2	10.0
Average minimum temperature(℃)	-15.9	-10.6	-2.7	5.5	11.9	16.5	18.6	16.8	10.5	2.6	-5.3	-12.7
Extreme minimum temperature(℃)	-27.7	-25.8	-15.2	-11.7	-1.5	7.0	9.4	5.4	0.8	-9.4	-21.6	-28.6
Average precipitation(mm)	1.3	1.5	1.2	2.0	3.9	6.6	7.3	5.3	3.3	3.3	2.0	1.3
Precipitation days	1.7	1.1	1.0	1.5	2.0	3.6	4.4	3.4	2.0	1.4	1.0	1.8
average wind speed(m/s)	1.4	1.6	2.2	2.5	2.2	1.9	1.7	1.6	1.4	1.4	1.4	1.3

Tab.3[30]

Electricity demand

Electric power of common household appliances:

Microwave oven about 1000W × 1h = 1kwh AC

Electric water heater about 1000W × 1h = 1kwh AC

Washing machine about 500W × 1h = 0.5kwh AC

TV set about (40 w~200w)--75w × 2h = 0.15kwh DC

Range hood about 140W × .5h = 0.07kwh DC

Refrigerator about 100W × 8h = 0.8kwh AC

Electric fan about 100W × 1h =0.01kwh DC

2--Lamps about 40w × 4h = 0.32kwh DC

Total = 3.85kwh per day

Electricity demand in Tianshan District: There are 118 families

Electricity demand = 118 × 3.85kwh = 454.3kw h(for a day)

For a year 365 × 454.3kwh = 165819.5kwh year

There are also 17 Tourist attraction service club = 12.6kwh × 17 =214.2 Kwh day

For a year 365 × 214.2kwh = 78183kwh year

Total demand for a day: 454.3＋214.2=668.5kwh (for a day)

Total demand for a year: 244002.5kwh (for a year)

The average real consumption (668.5kwh / day) is lower than the calculated one (802.2 kWh / day) since the losses of several elements and the margin of safety have been introduced.

Annual solar radiation in China

Regional category	region	Annual solar radiation		Annual sunshine hours	Annual average sunshine time under standard illumination
		MJ/m2. Year	kwh/m2. year		
First level	NorthernNingxia, northern Gansu,southernXinjiang, Tibet	6680--8400	1855--2333	3200--3300	5.08--6.3
Secondary	Northwestern Hebei,southernInnerMongolia,southeastern Xinjiang	5852--6680	1625--1855	3000--3200	4.45--5.08
Third level	Shandong, Henan, northern Xinjiang	5016--5852	1393--1625	2200--300	3.8--4.45
Level four	Hunan, Hubei, Guangxi	4190--5016	1163--1393	1400--2200	3.1--3.8

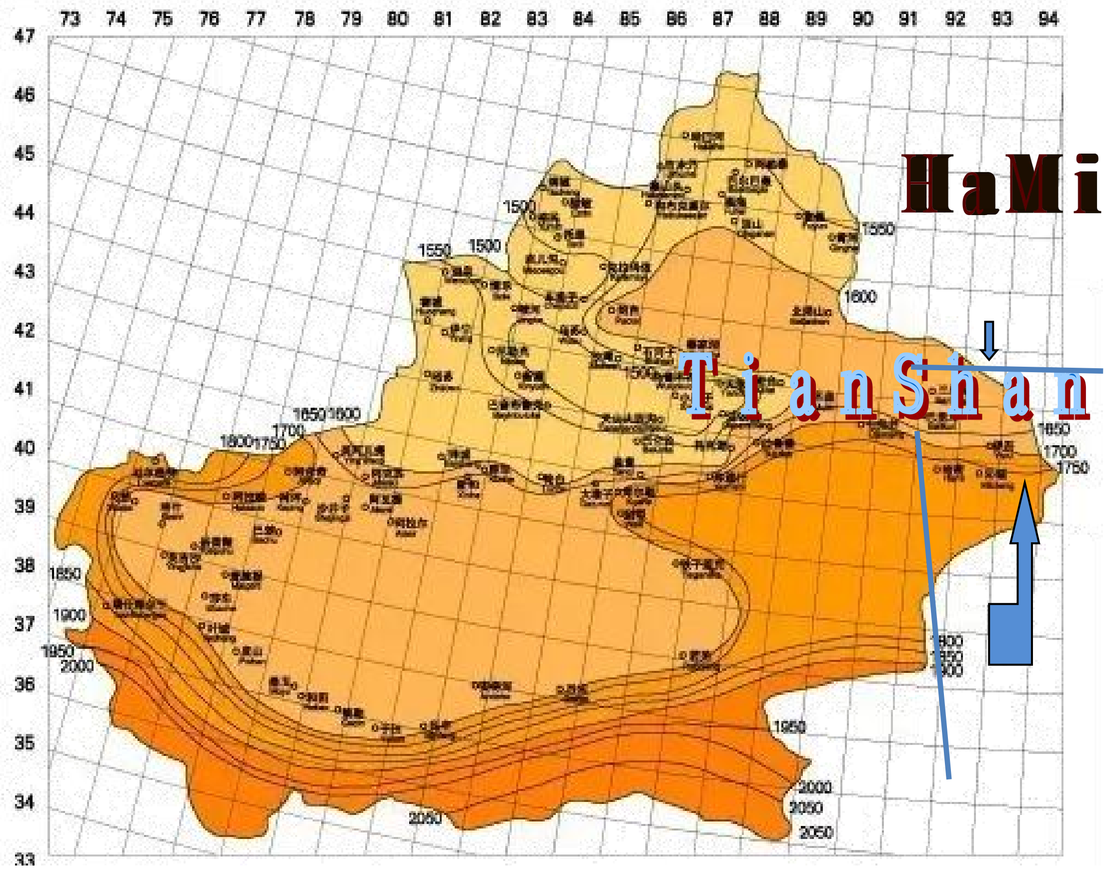
Solar irradiance in HAMI

month	1	2	3	4	5	6	7	8	9	１０	１１	１２

irradiance	7.78	11.6	18.11	18.53	25.52	25.11	24.17	20.57	16.57	12.24	8.33	6.56
									Annual		5944.42(MJ/m²)	

Tab.4[31]

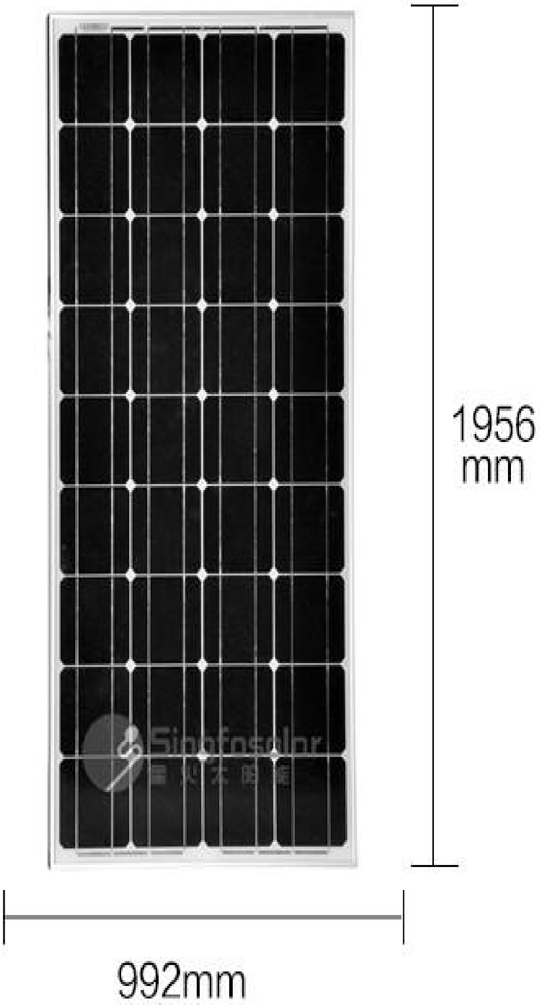
Solar radiation map　　ｉｎ　Ｘｉｎｊｉａｎｇ



From the solar radiation map, we can see that the annual solar radiation in the project area is 1750 kwh/㎡ and we can use to Annual average sunshine time under standard illumination(4.5h)

Secondary	Northwestern Hebei,southernInnerMongolia,southeastern Xinjiang	5852--6680	1625--1855	3000--3200	4.45--5.08

Purpose solar panel sample



modelSolar cell－ＳＦＭ３００

Peak power –(Pmax):300w

Peak voltage – (Vmp):36V

Open circuit voltage(Voc):43.2V

Peak current(Imp):8.33A

Short circuit current(Isc):9.17A

Number of cells:72(6×12)

Size:1956 ㎜ × 992 ㎜

Solar cell: Mono crystalline silicon

Weight:27.3kg

Price:97€

Ambient temperature:25℃,AM=1.5

Maximum system voltage:1000vDC(IEC)/600vDc (UL)

Solar panel working environment:-40℃ to +85℃[32]

Inverter

产品型号	PWS1-250K	PWS2-250K	PWS1-250K-NA
直流侧参数			
直流电压范围	500~850V	250~800V	500~850V
直流最大电流	550A	650A	550A
最大直流功率	275kW	275kW	275kW
交流并网参数			
额定输出功率	250kW	250kW	250kW
额定电网电压	400V	400V	480V
电网电压范围	±15%	±15%	±10%
电网频率	50Hz/60Hz±2.5Hz	50Hz/60Hz±2.5Hz	60Hz±0.5Hz
交流额定电流	360A	360A	301A
输出THDi	≤3%	≤3%	≤3%
并网功率因数		-1~+1	
交流离网参数			
交流离网电压	400V	400V	480V
交流电压范围		±10%	
交流离网频率	50Hz/60Hz	50Hz/60Hz	60Hz
离网输出THDu		≤2%（线性负载）	
系统参数			
整机最高效率	97.3%	95.5%	97.3%
接线方式		三相四线	
冷却方式		强制风冷	
噪声		70dB	
温度范围		-20℃~50℃	
防护等级		IP20	
海拔		3000m	

Name of tip :PWS1-250kw

Input : Max V DC 1000v(500-850v)

Input : Max I DC 550A

Conversion rate : 97%

Weight : 1280kg

range of working temperature : -20℃~50℃

Price : 8580￥

[33]

Planning storage electric field

The average consumption in Ah / day will be (we assume a 24 V battery):

Qah = Lmd / Vbat = 668.5kwh/24v=27854.16Ah

Total annual consumption and the annual average:

LT= Lmd·365=668.5kwh×365day=251302.5kwh.year

Lma=LT/365=251302.5kwh/365=668.5kwh/day

Details of the place where the installation will take to know the irradiation that we will have.

The global solar radiation data of the location of the house will be searched using the PVGIS:

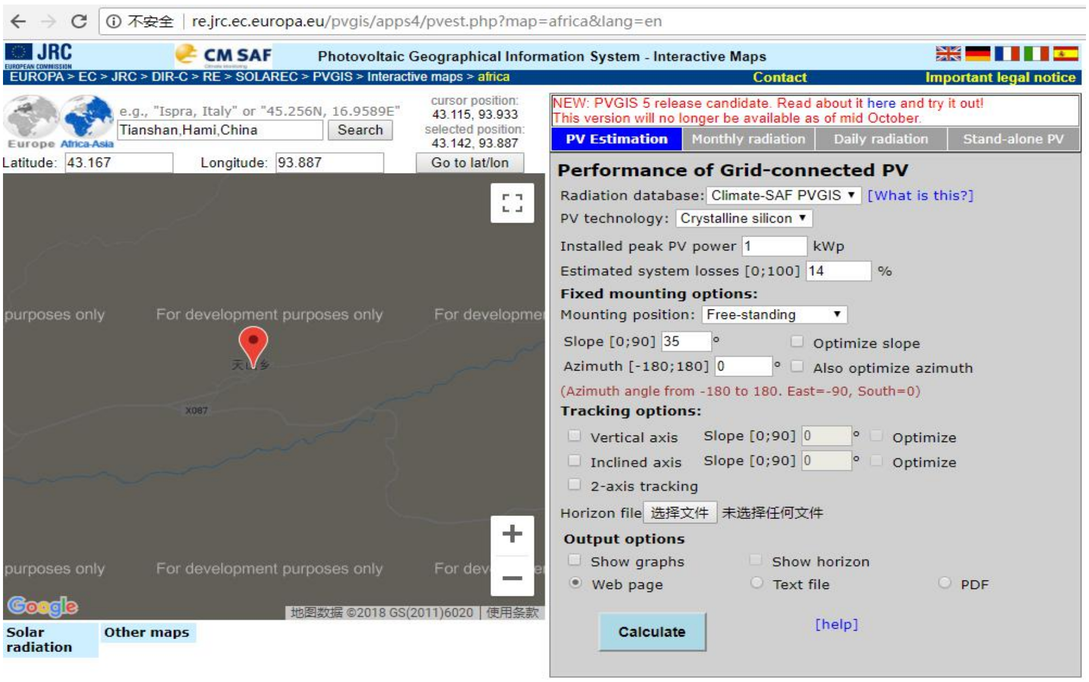


Fig.24[34]

the "Radiation Table" (Wh / m2 / day) according to the inclinations. In the case of Hami TainSHan:

PVGis estimates of solar electricity generation

Location: 43°8'24" North, 93°52'49" East, Elevation: 1607 ma.s.l.,

Solar radiation database used: PVGIS-CMSAF

Nominal power of the PV system: 1.0 kW (crystalline silicon)

Estimated losses due to temperature and low irradiance: 7.2% (using local ambient temperature)

Estimated loss due to angular reflectance effects: 2.5%

Other losses (cables, inverter etc.): 14.0%

Combined PV system losses: 22.2%

Month	inclination =35°	inclination =40°	inclination =45°	inclination =50°	inclination =55°	inclination =60°
Jan	3.64	3.79	3.91	4.01	4.09	4.13
Feb	4.16	4.27	4.36	4.42	4.46	4.46
Mar	5.09	5.14	5.17	5.16	5.13	5.06
Apr	4.91	4.87	4.80	4.71	4.58	4.43
May	4.97	4.86	4.72	4.56	4.37	4.16
Jun	4.56	4.43	4.27	4.10	3.39	3.67
Jul	4.51	4.39	4.25	4.09	3.39	3.69
Aug	4.56	4.50	4.41	4.29	4.15	3.99
Sep	4.76	4.77	4.76	4.72	4.66	4.56
Oct	4.59	4.70	4.77	4.82	4.83	4.82
Nov	3.77	3.91	4.03	4.12	4.18	4.22
Dec	2.95	3.08	3.19	3.27	3.34	3.38
Yearly average	**4.37**	**4.39**	**4.39**	**4.35**	**4.30**	**4.21**

Tab.5

Dimensioning of the photo voltaic generator

Calculate the optimal inclination for our installation, for this we apply the criterion of the Critical Month, so, it is necessary to prepare from the table of radiations, the Table of Quotients "Consumption / Radiation that is the one shown below:

Month	inclination =35°	inclination =40°	inclination =45°	inclination =50°	inclination =55°	inclination =60°
Jan	4180	4360	4520	4650	4740	4800
Feb	4950	5090	5210	5290	5330	5340
Mar	6300	6380	6410	6400	6350	6260
Apr	6410	6360	6270	6140	5970	5760
May	6660	6510	6320	6100	5840	5550
Jun	6270	6090	5870	5620	5340	5040
Jul	6300	6130	5930	5700	5440	5140
Aug	6320	6230	6110	5940	5740	5500
Sep	6330	6350	6340	6290	6190	6060
Oct	5840	6980	6090	6150	6170	6150
Nov	4520	4700	4850	4970	5050	5100
Dec	3420	3580	3720	3830	3910	3970
Yearly average	5630	5650	5640	5590	5510	5390

Tab.6

For each inclination we look for the highest value of each column because they correspond to the time of year where the relationship between energy consumption and available radiation will be more excellent, this will mean an oversizing for the other months. It will be December, which is when there is less solar radiation. Once these values are known, the smallest of them is chosen below, to avoid excessive oversizing(3970 and 60 º). That is, our installation must incline 60º. This option is selected because it delivers the maximum amount of energy during the month in which irradiation is lower, this is equivalent to choose a sizing option based in the “worst month.”

The number of modules needed to generate the energy that is demanded each day will be:

$PG.max = FSG \cdot Ldm / Gdm/ISTC = (1.2 \times 668.5 kwh/dia) \div (3970 wh/㎡ \div 1000 w/㎡)$

$802.2 kwh/3.97 h = 202.07 kw$

$NT = PG.max / Pmax = 202.07 kw/300 wp = 673.6 \approx 674$

Lmdcrit) the monthly average daily consumption for the critical month, "Consumption Table," (in this case, it is always the same [802.2 Kwh / day], since the daily consumption is constant throughout the year)

(PMPP) the peak power of the module under standard conditions of measurement STC, in this case, we are using the model SFM300 of the manufacturer, with 300 watts of peak power in STC.

(HPScrit) are the peak sun hours of the critical month calculated from the "Radiation Table," that is: Irradiation of the critical month (December 60º) / 1000 W / m2 = 3,38 HPS

(PR) The global operating factor that varies between 0.65 and 0.90. We will use 0.90.

Regarding the connection of the modules calculated in series or parallel, bearing in mind that the SFM300 has a Vmax = 36 Volt., We do:

NT=674， panel(Pmax)=300wp， total demand=202.07kw

total demand = NT · Pmax = 674×300wp =202.2kw≈202.07kw

Voltage of inverter 1000V , panel Vmax = 36 Volt , total panel 674

$N_{serie} = V_{inverter} / V_{MOD\ MPP}$

Ns = 1000V/36V=27.7≈28

$N_{PARALLEL} = NT / N_{SERIE}$ = 674/28 = 24

NT = $N_{PARALLEL} \times N_{serie}$ = 24 × 28 = 672 ≈ 674(panel)

If a regulator with maximum power point tracking is not going to be installed, another criterion must be used, that of Amp-Hour. Now it will be the battery that marks the voltage of the system (12, 24, 48 Volt.) Also, will seldom reach the point of the maximum power of the modules used. We initially have the average energy consumption in Ah/day calculated above:

QAh = Lmd / VBat = 802.2kwh/24=33425Ah

$I_{GFV,MPP}$ = QAh / HPScrit = 33425/3.38 = 9889.05 A

$N_{PARALLEL} = I_{GFV,MPP} / I_{MOD,MPP}$ = 9889.05 / 8.33 = 1187.2

Dimensioning of the accumulation system (number of batteries).

DeDepth of Maximum Seasonal Discharge (PDmax, e) = 70% = 0.7

Depth of Maximum Daily Discharge (PDmax, d) = 15% = 0.15

Number of Days of Autonomy (N) = 5

Temperature correction factor (FCT = 1.5).

We now calculate the required nominal capacity of the batteries according to the seasonal and daily discharge depth. The largest one will be the one we select. The theoretical capacity of the battery according to the maximum daily discharge (Cnd) and Nominal size of the array according to the maximum seasonal release (Cne):

Cnd(wh) = Lmd / PDmax, d · FCT = 802200 / 0.15×1.5 = 3565333.33wh

Cnd(Ah) = Cnd(wh) / VBAT = 3565333.33/24 = 148555.56 Ah

Cne(wh) = Lmd · N / PDmax, d · FCT = 802200×5 / 0.7×1.5= 3820000wh

Cne(Ah) = = Cne(wh) / VBAT = 3820000wh / 24 = 159166.67 Ah

So we would choose the largest, that is, the nominal capacity of the batteries would be, at least, Cne = 159166.67 Ah

Dimensioning of the regulator

We must calculate the maximum current that the regulator will support, at its input and its output. To calculate the input current to the regulator we make the product of the short-circuit current of a PV module, in this case, that of the SFM300 is Isc = 9.17A and multiply by the number of branches in parallel (1187.2) calculated previously. A safety factor (25%) will be applied to prevent damage to the regulator:

Gentry = 1.25 × IMOD,SC · NP = 1.25 × 9.17 × 1187 = 13605.98A

For the calculation of the output current we have to evaluate the powers of the DC loads and the AC loads (the inverter's performance is supposed to be 95%):

IOut = 1.25 · (PDC + PAC / ηinv)/VBAT= 1.25× ｛(40+75+140+100)+2600/0.95}/24 = 161.03A

Thus, the regulator must withstand a current, at least 13605.98A at its input and 161.03A at its output.

Dimensioning of the inverter

We have to calculate the sum of the powers of the alternating loads. In our case, it would be the washing machine(500W), Microwave oven (1000W)， Electric water heater (1000W) and the Refrigerator (100W) and apply a safety margin of 20%:

Pinv = 1.2 · PAC = 1.2 × (500+1000+1000+100)=3120w

Thus, an inverter of approximately 3120w will be necessary.

However, we must take into account the starting peaks of household appliances, such as refrigerators, washing machines etc, which means that for their start they will demand more power than the nominal, sometimes up to 4 or 5 times more than the rated power planned. For this reason, to avoid problems in the correct operation of our installation, it is advisable to make an oversize that includes the starting peaks:

Pinv = 1.2 · PAC = 1.2 × (500×4+1000+1000+100×4)= 4400w

Therefore, our investor should cover, at least, 4400w of demand to have the needs of the home well covered, including peak demand for the engine start of the washing machine.

Battery part

In this project, we have chosen four different battery types used in Photovoltaic systems. The battery market offers a wide range of battery types, supplied by different brands, for this application. However, we have chosen those that the manufacturer gave us the data, among others, of the amount of charge/discharge cycles that a battery can deliver at different depths of discharge. Besides, we have chosen a battery with the same capacity: 100 Ah.

Below are the batteries used in this project and the data supplied by the manufacturer.

①Lead-acid batteries

BASIC CHARACTERISTICS

Model Name : 6GFM100-12

Rated voltage vdc: 12   Floating charge voltage vdc : 13.5-13.8

Equal charge voltage : 14.5-14.9

Capacity retention rate : ≥ 96%(month)

Float design life : 6 (year,25℃)

Discharge temperature : -15℃~+50℃

Self-discharge per month : ≤ 4%

N°cycle life:50% DOD ≥ 600 times

Recharge time: 8-16h

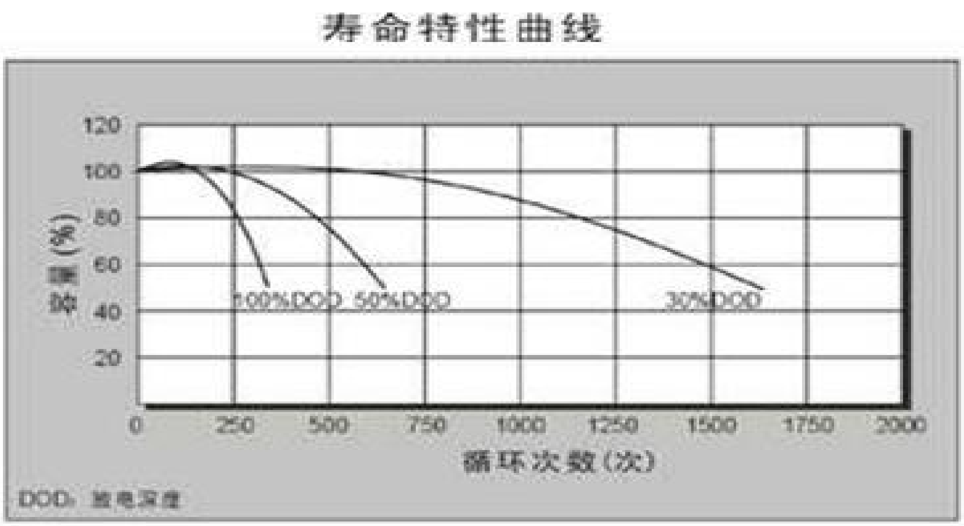
Wide range of capabilities : (17Ah~200Ah)

Price : (12V,100Ah→97€)(24V， 100Ah,→110€)(48V,100Ah,→123€)

(30kg, 42kg,50kg)

the form below

Nº Cycle life versus remaining capacity, at different DODs (100 %, 50 % and 30%).



②Lithium iron phosphate battery

Model Name : VikLi

1, nominal voltage: a variety of models(2V~48V)

2, nominal capacity: a variety of models(20Ah~500Ah)

3, weight: a variety of models;(5Kg~120Kg)

4, internal resistance: a variety of models;

5, standard continuous discharge current: 0.5C;

6, the maximum continuous discharge current: 1C;

7, cycle life: 80% DOD ≥ 3000 times

8, working temperature: charging: 0℃~ +45℃

Discharge: -20℃ ~+60℃

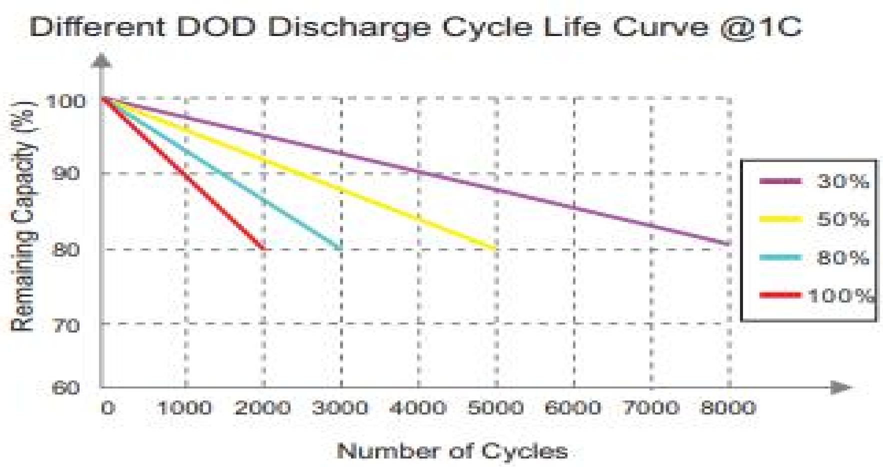
9,Self-discharge per month : <3%

10. Material system: iron lithium

Recharge time: 4-6h

Price :(12V,100Ah→123€)(24V,100Ah→155€)(48V,100Ah→175€)

Nº Cycle life versus remaining capacity, at different DODs (100 %, 80%， 50 % and 30%).



③Colloidal battery

Model Name : LiabBang 6-FM-100

Rated voltage vdc: 12 Floating charge voltage vdc : 13.5-13.8

Equal charge voltage : 14.5-14.9

Capacity retention rate : ≥ 98%(month)

Float design life :7-10(40Ah or more, year,25℃)

Discharge temperature : -15℃~+50℃

Self-discharge per month : ≤ 5%

N°cycle life: 50% ≥ 2000 times

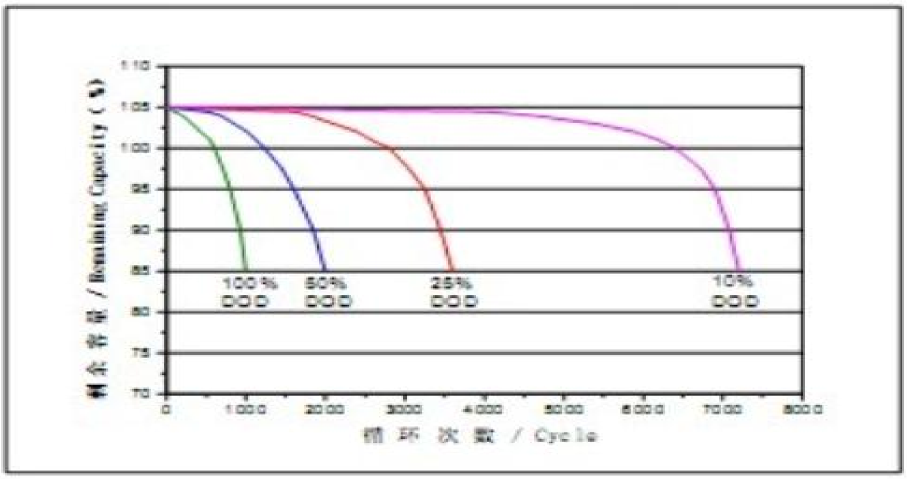
Recharge time: 3-5h

Wide range of capabilities : (1.2Ah~200Ah)

Price : (12V,100Ah→116€)(24V,100Ah→148€)(48V,100Ah→161¥)

№ Cycle life versus remaining capacity, at different DODs (100 %, 50 % and 25%，10%).

(30kg, 42kg,50kg)



[35]

④Lithium iron phosphate battery(expensive)

Brand Name : BULLSPOWER

Nominal Voltage:12V

Nominal Capacity:100Ah, 10Ah -100Ah

cycle life:100% DOD >2 000 times

working temperature: -20 to 60 deg.C

Self-discharge per month : 1~2% per month;

Price : 360€

Other price : (12v,100Ah→360€)(24v,100Ah→406€)(48v,100Ah→496€)

№ Cycle life versus remaining capacity, at different DODs (100 %, 80%， 50 % and 30%).

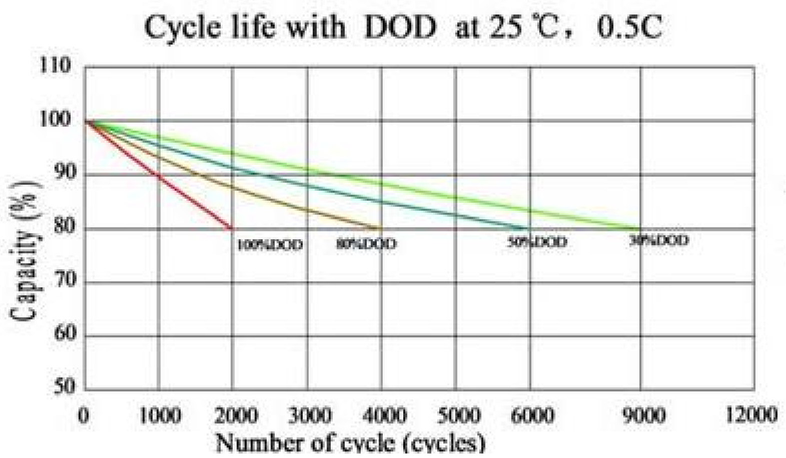


Fig. 24[36]

Simulation of the Battery Bank

We have to simulate the number of batteries that we need to supply the power calculated previously top.max = FSG · Ldm / Gdm/ISTC = (1.2×668.5kwh/dia)÷(3970wh/㎡÷1000w/㎡)

802.2kwh/3.97h = 202.07kw

For this simulation, we have used the calculated number of all the demand battery and capacity of electricity.   Fig.25[37]

Fill in the following and click on the Calculate button...

Item 1. Insert your watt hours needed per day. This is the value you got from Step 1, Part C in working out your power needs.
Watt hours needed per day: 802200 (Wh/day)

Item 2. Enter the voltage for your battery bank. This is usually 12, 24 or 48, the larger the system the higher the value. If you don't know then enter 24 for now. You may have to return to this step later.
Battery bank voltage: 12 (V)

Calculation: 802200 Wh/day / 12 V = 66850.0 amp hours/day

Item 3. Enter the number of days you expect to be cloudy in a row i.e. the number of days in a row your solar panels won't be producing power. Your batteries will need to store enough power to supply your appliances during those days.
Days without sun: 5 (days)

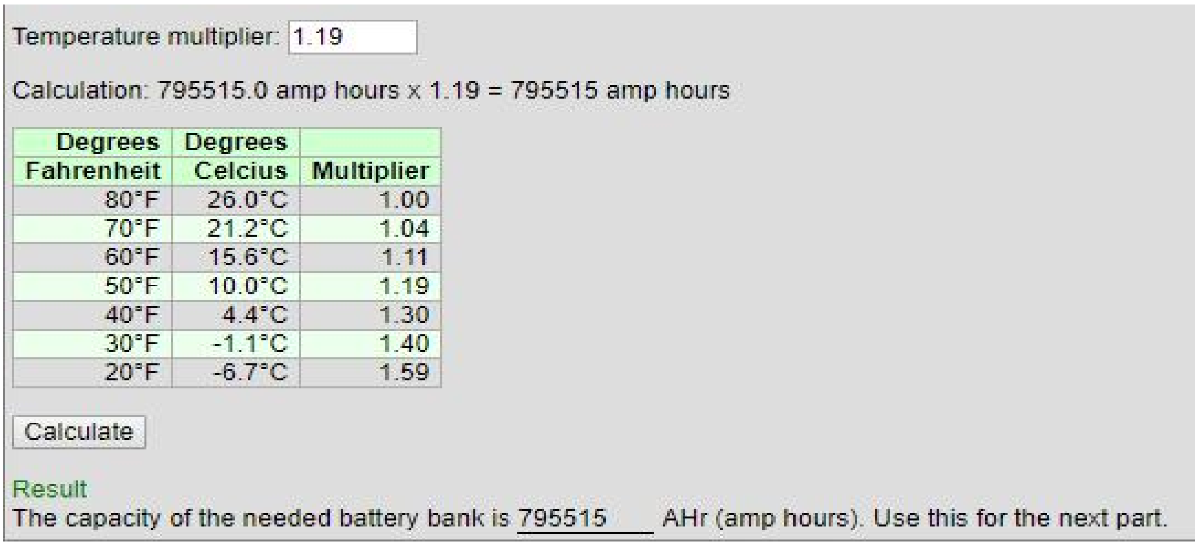
Calculation: 66850.0 amp hours/day x 5 days = 334250.0 amp hours

Item 4. Normally you don't want to discharge more than 50% of your battery's capacity before charging them back up again. The more you discharge your batteries before recharging them, the shorter their useful lifetime. This means if you don't discharge more than 20% of their capacity then they'll last even longer than if you normally discharge 50% of their capacity. But only discharging them by 20% means the 20% used will have to meet all your power needs. This means you'll need a larger battery bank since you'll only ever use 20%. So the tradeoff is upfront cost versus battery lifetime. That's why the rule-of-thumb is 50%.
Depth of discharge: 50 (%)

Calculation: 334250.0 amp hours x [1 / (50 / 100)] = 668500.0 amp hours

Item 5. Colder temperatures have a negative effect on the capacity of your battery bank. If your battery bank is always indoors in a heated area then you don't have a problem. But if they're stored in an unheated area during the winter then you'll need to account for this.

Select a multiplier from the following table that corresponds to the coldest average temperature you expect in the area where you'll be keeping your batteries. It must be around this average for at least a few days in a row.


Temperature multiplier: 1.19

Calculation: 795515.0 amp hours x 1.19 = 795515 amp hours

Degrees Fahrenheit	Degrees Celcius	Multiplier
80°F	26.0°C	1.00
70°F	21.2°C	1.04
60°F	15.6°C	1.11
50°F	10.0°C	1.19
40°F	4.4°C	1.30
30°F	-1.1°C	1.40
20°F	-6.7°C	1.59

Calculate

Result
The capacity of the needed battery bank is 795515 AHr (amp hours). Use this for the next part.

The table below is number of all the battery in these percentage : (100%.80%,50%,30%,25%,10%) cycles life

Battery/percentage	100%	80%	50%	30%	25%	10%
Quantity of 12V 100Ah	3978	4972	7955	13259	15910	39776
Quantity of 24V 100Ah	1989	2486	3978	6629	7955	19888
Quantity of 48V 100Ah	994	1243	1989	3315	3976	9944

Tab.7

in this simulation we have always used the capacity of 100 Ah and four different battery voltages: 12 V, 24 V, and 48 V.

After that, we have taken into account the number of charge/discharge cycles that each battery provides at different DoDs. Finally, we have obtained the final price of the battery bank, considering an operation time of (50,20,10,4) years.

Next tables show the results obtained from the simulation of the four battery analyzed in this project.

All prices in the case study are given in YUAN (￥) but fully reflected prices in Hami Tianshan. Used convert of yuan to the euro was 1 € = 7.75 ￥.the exchange rate of this money belongs only to the day the paper was written. the former exchange rate will change with economic conditions.

①Lead-acid batteries

Battery/percentage	100%	50%	30%
Quantity of 12V 100Ah, 97 €	3978	7955	13259
Total price€	385866	771635	1286123
Quantity of 24V 100Ah, 110 €	1989	3978	6629
Total price€	218790	437580	729190
Quantity of 48V 100Ah, 123 €	994	1989	3315
Total price€	122262	244647	407745

Tab.8

②Lithium iron phosphate battery

Battery/percentage	100%	80%	50%	30%
Quantity of 12V 100Ah, 123 €	3978	4972	7955	13259
Total price€	489294	611556	1199865	1630857
Quantity	1989	2486	3978	6629

of 24V 100Ah, 155 €				
Total price€	308295	385330	616590	1027495
Quantity of 48V 100Ah, 175 €	994	1243	1989	3315
Total price€	173950	217525	348075	580125

Tab.9

③Lithium iron phosphate battery(expensive)

Battery/percentage	100%	80%	50%	30%
Quantity of 12V 100Ah, 360 €	3978	4972	7955	13259
Total price€	1432080	1789920	2863800	4773240
Quantity of 24V 100Ah, 406 €	1989	2486	3978	6629
Total price€	807534	1009316	1615068	2691374
Quantity of 48V 100Ah, 496 €	994	1243	1989	3315
Total price€	493024	616582	986544	1644240

Tab.10

④Colloidal battery

Battery/percentage	100%	50%	25%	10%
Quantity of 12V 100Ah, 116	3978	7955	15910	39776

€				
Total price€	461448	922780	1845560	4614016
Quantity of 24V 100Ah,148 €	1989	3978	7955	19888
Total price€	294372	588744	1177340	2943424
Quantity of 48V 100Ah.161 €	994	1989	3976	9944
Total price€	160034	320229	640136	1600984

Tab.11

Analysis parameter and economy of battery

In this section analysis every battery cycles life and economy for choose better one of battery.each battery has its cycle life percentage and corresponding update times.

①Lead-acid batteries(for 50 year)

Lead-acid batteries	100%	50%	30%
cycle life	300time	600time	1500time
Number of replacement	300day→1time	600day→1time	1500day→1time
For50year=18250day	61time	30time	12time
12V,100Ah quantity	242658	238650	159108
Total price	23537826€	23149050€	15433476€
24V.100Ah quantity	121329	119310	79548
Total price	13346190€	13124100€	8750280€
48V.100Ah quantity	60634	29820	11928

Total price	7457982€	3667860€	1467144€

Tab.12

Lead-acid batteries(for 20 year)

Lead-acid batteries	100%	50%	30%
cycle life	300 time	600 time	1500 time
Number of replacement	300day→1time	600day→1time	1500day→1time
For20year=7300day	25 time	13 time	5 time
12V,100Ah quantity	99450	103415	66295
Total price	9646650€	10031255€	6430615€
24V.100Ah quantity	49725	51714	33145
Total price	5469750€	5688540€	3645950€
48V.100Ah quantity	24850	25857	16575
Total price	3056550€	3180411€	2038725€

Tab.13

Lead-acid batteries(for 10 year)

Lead-acid batteries	100%	50%	30%
cycle life	300 time	600 time	1500 time
Number of replacement	300day→1time	600day→1time	1500day→1time
For10year=3650day	13 time	6 time	3 time
12V,100Ah quantity	51714	47730	39777
Total price	5016258€	4629810€	3858369€
24V.100Ah quantity	25857	23868	19887
Total price	2844270€	2625480€	2187570€
48V.100Ah quantity	12922	11934	9945
Total price	1589406€	1467882€	1223235€

Tab.14

Lead-acid batteries(for 4 year)

Lead-acid batteries	100%	50%	30%
cycle life	300 time	600 time	1500 time

Number of replacement	300day→1time	600day→1time	1500day→1time
For4year=1460day	5 time	3 time	1 time
12V,100Ah quantity	19890	23865	13259
Total price	1929330€	2314905€	1286123€
24V.100Ah quantity	9945	11934	6629
Total price	1093950 €	1312740€	729190€
48V.100Ah quantity	4970	5967	3315
Total price	611310€	733941€	407745€

Tab.15

②Lithium iron phosphate battery(for 50 year)

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	3000 time	5000 time	8000 time
Number of replacement	2000day-1time	3000day-1time	5000day-1time	8000day-1time
For50year=18250day	9.1time≈10	6.1≈7time	3.65≈4time	2.3time≈3
12V,100Ah quantity	39780	34804	31824	39777
Total price	4892940€	4280892€	3914352€	4892571€
24V.100Ah quantity	19890	17402	15912	19887
Total price	3082950€	2697310€	2466360€	3082485€
48V.100Ah quantity	9940	8701	7956	9945
Total price	1739500€	1522675€	1392300€	1740375€

Tab.16

Lithium iron phosphate battery(for 20 year)

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	3000 time	5000 time	8000 time
Number of replacement	2000day-1time	3000day-1time	5000day-1time	8000day-1time
For20year=7300day	4 time	3 time	2 time	1 time

12V,100Ah quantity	15912	14916	15910	13259
Total price	1957176€	1834668€	1956930€	1630857€
24V.100Ah quantity	7956	7458	7956	6629
Total price	1233180€	1155990€	1233180€	1027495€
48V.100Ah quantity	3976	3729	3978	3315
Total price	695800€	652575€	696150€	580125€

Tab.17

Lithium iron phosphate battery(for 10 year)

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	3000 time	5000 time	8000 time
Number of replacement	2000day-1time	3000day-1time	5000day-1time	8000day-1time
For10year=3650day	2 time	2 time	1 time	1 time
12V,100Ah quantity	7956	9944	7955	13259
Total price	978588€	1223112€	978465€	1630857€
24V.100Ah quantity	3978	4972	3978	6629
Total price	616590€	770660€	616590€	1027495€
48V.100Ah quantity	1988	2486	1989	3315
Total price	347900€	435050€	348075€	580125€

Tab.18

Lithium iron phosphate battery(for 4 year)

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	3000 time	5000 time	8000 time
Number of replacement	2000day-1time	3000day-1time	5000day-1time	8000day-1time
For4year=1460day	1 time	1 time	1 time	1 time
12V,100Ah quantity	3978	4972	7955	13259
Total price	489294€	611556€	978465€	1630857€
24V.100Ah quantity	1989	2486	3978	6629

Total price	308295€	385330€	616590€	1027495€
48V.100Ah quantity	994	1243	1989	3315
Total price	1753950€	217525€	348075€	580125€

Tab.19

③Lithium iron phosphate battery[(for 50 year)expensive]

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	4000 time	6000 time	9000 time
Number of replacement	2000day-1time	4000day-1time	6000day-1time	9000day-1time
For50year=18250day	9.1time≈10	5 time	3.1≈4 time	2.1≈3time
12V,100Ah quantity	39780	24860	31820	39777
Total price	14320800€	8949600€	11455200€	14319720€
24V.100Ah quantity	19890	12430	15912	19887
Total price	8075340€	5046580€	6460272€	8074122€
48V.100Ah quantity	9940	6215	7956	9945
Total price	4930240€	3082640€	3946176€	4932720€

Tab.20

Lithium iron phosphate battery[(for 20 year)expensive]

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	4000 time	6000 time	9000 time
Number of replacement	2000day-1time	4000day-1time	6000day-1time	9000day-1time
For20year=7300day	4time	2 time	2 time	1time
12V,100Ah quantity	15912	9944	15910	13259
Total price	5728320€	3579840€	5727600€	4773240€
24V.100Ah quantity	7956	4972	7956	6629
Total price	3230136€	2018632€	3230136€	2691374€
48V.100Ah quantity	3976	2486	3978	3315

Total price	1972096€	1233056€	1973088€	1644240€

Tab.21

Lithium iron phosphate battery[(for 10 year)expensive]

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	4000 time	6000 time	9000 time
Number of replacement	2000day-1time	4000day-1time	6000day-1time	9000day-1time
For10year=3650day	2 time	1 time	1 time	1time
12V,100Ah quantity	7956	4972	7955	13259
Total price	2864160€	1789920€	2864160€	4773240€
24V.100Ah quantity	3978	2486	3978	6629
Total price	1615068€	1009316€	1615068€	2691374€
48V.100Ah quantity	1988	1243	1989	3315
Total price	986048€	616528€	986544€	1644240€

Tab.22

Lithium iron phosphate battery[(for 4 year)expensive]

Lithium iron phosphate battery	100%	80%	50%	30%
cycle life	2000 time	4000 time	6000 time	9000 time
Number of replacement	2000day-1time	4000day-1time	6000day-1time	9000day-1time
For4year=1460day	1time	1 time	1 time	1time
12V,100Ah quantity	3978	4972	7955	13259
Total price	1432080€	1789920€	2863800€	4773240€
24V.100Ah quantity	1989	2486	3978	6629
Total price	807534€	1233056€	1615068€	2691374€
48V.100Ah quantity	994	1243	1989	3315
Total price	493024€	616528€	986544€	1644240€

Tab.23

④Colloidal battery(for 50 year)

Colloidal battery	100%	50%	25%	10%
cycle life	1000	2000	3500	7500
Number of replacement	1000day-1time	2000day-1time	3500day-1time	7500day-1time
For50year=18250day	19 time	10 time	6 time	3 time
12V,100Ah quantity	75582	79550	95460	119328
Total price	8767512€	9228960€	11073360€	13842048€
24V.100Ah quantity	37791	39780	47730	59664
Total price	5593068€	5887440€	7064040€	8830272€
48V.100Ah quantity	18886	19890	23856	29832
Total price	3040646€	3202290€	3840816€	4802952€

Tab.24

Colloidal battery(for20 year)

Colloidal battery	100%	50%	25%	10%
cycle life	1000	2000	3500	7500
Number of replacement	1000day-1time	2000day-1time	3500day-1time	7500day-1time
For20year=7300day	8 time	4time	3 time	1 time
12V,100Ah quantity	31824	31820	47730	39776
Total price	3691584€	3691120€	5536680€	4733344€
24V.100Ah quantity	15912	15912	23865	19888
Total price	2354976€	2354976€	3532020€	2943424€
48V.100Ah quantity	7952	7956	11928	9944
Total price	1280272€	1280916€	1920408€	1600984€

Tab.25

Colloidal battery(for10 year)

Colloidal battery	100%	50%	25%	10%
cycle life	1000	2000	3500	7500
Number of replacement	1000day-1time	2000day-1time	3500day-1time	7500day-1time
For50year=3650day	4 time	2 time	2 time	1 time
12V,100Ah quantity	15912	15910	31820	39776
Total price	1845792€	1845560€	3691120€	4614016€
24V.100Ah quantity	7956	7956	15910	19888
Total price	1177488€	1177488€	2354980€	2943424€
48V.100Ah quantity	3976	3978	7952	9944
Total price	640136€	640458€	1280272€	1471712€

Tab.26

Colloidal battery(for4year)

Colloidal battery	100%	50%	25%	10%
cycle life	1000	2000	3500	7500
Number of replacement	1000day-1time	2000day-1time	3500day-1time	7500day-1time
For50year=1460day	2 time	1 time	1 time	1 time
12V,100Ah quantity	7956	7955	15910	39776
Total price	922896€	922780€	1845560€	4614016€
24V.100Ah quantity	3978	3978	7955	19888
Total price	588744€	588744€	1177340€	2943424€
48V.100Ah quantity	1988	1989	3976	9944
Total price	320068€	320229€	640136€	1600984€

Tab27

The figures below are batteries costs analysis chart between the selected percentages 50% and 30%.compare the costs changes between the two percentages finally choose the most suitable one.

The fig is for 48v 100A 50% cycles life

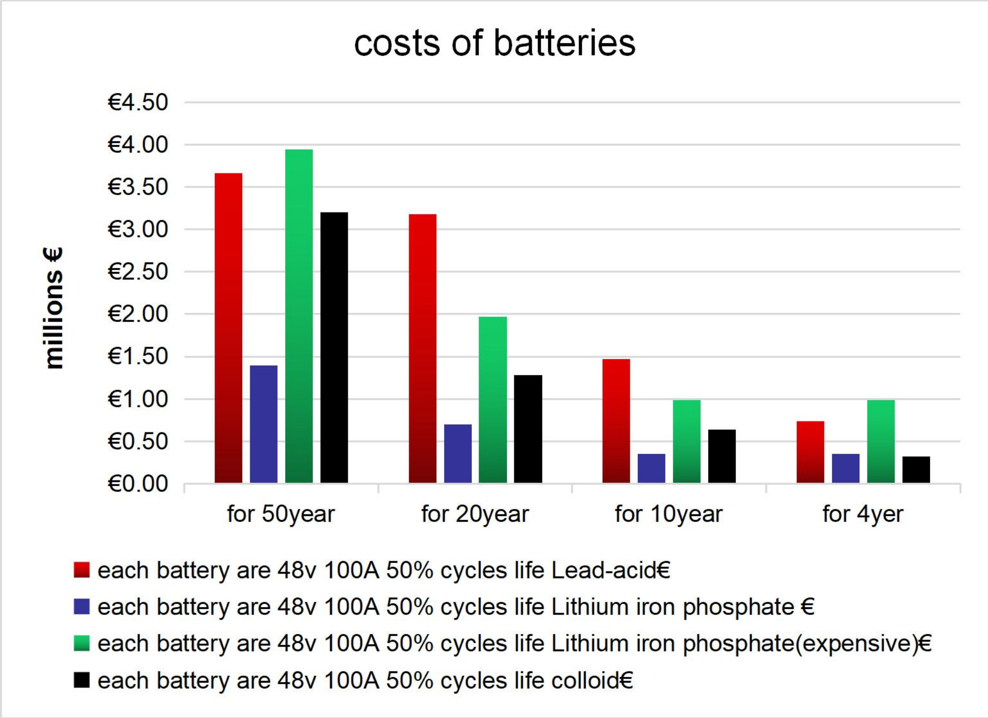


Fig.26

The fig is for 48v 100A 30% cycles life

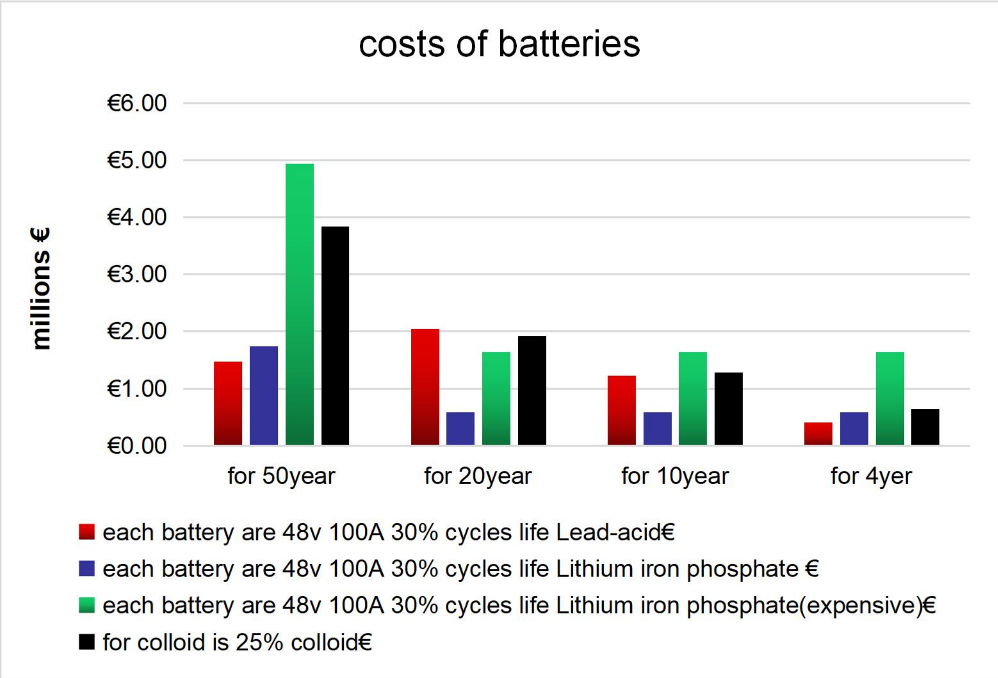


Fig.27

The fig is for 24v 100A 50% cycles life

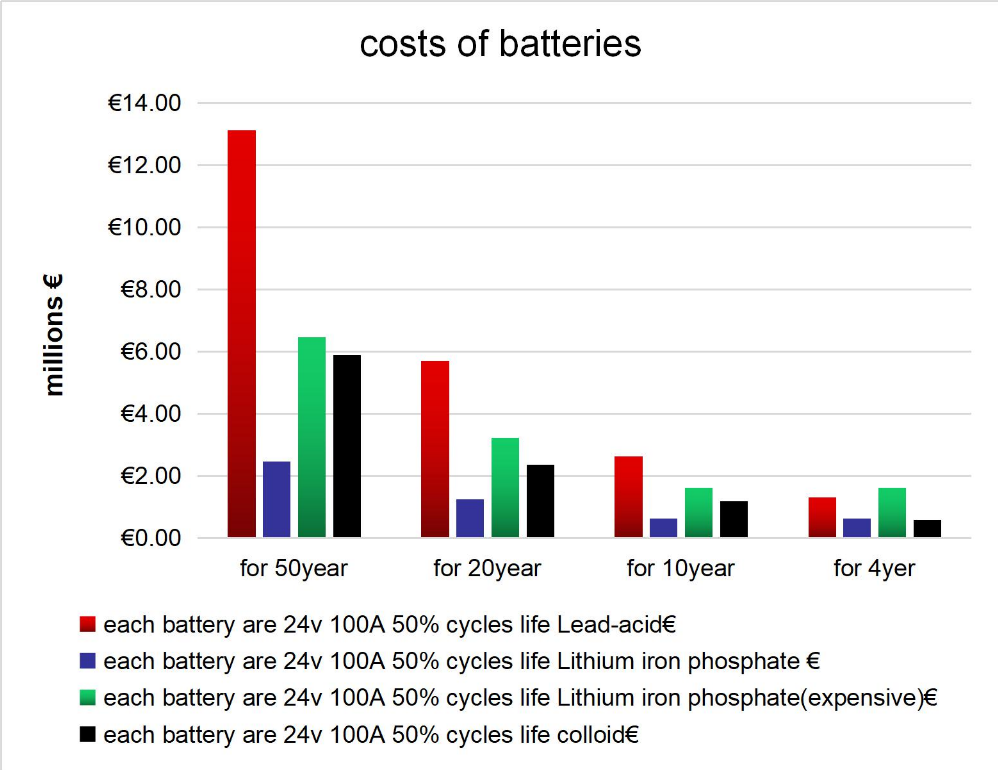


Fig.28

The fig is for 24v 100A 30% cycles life

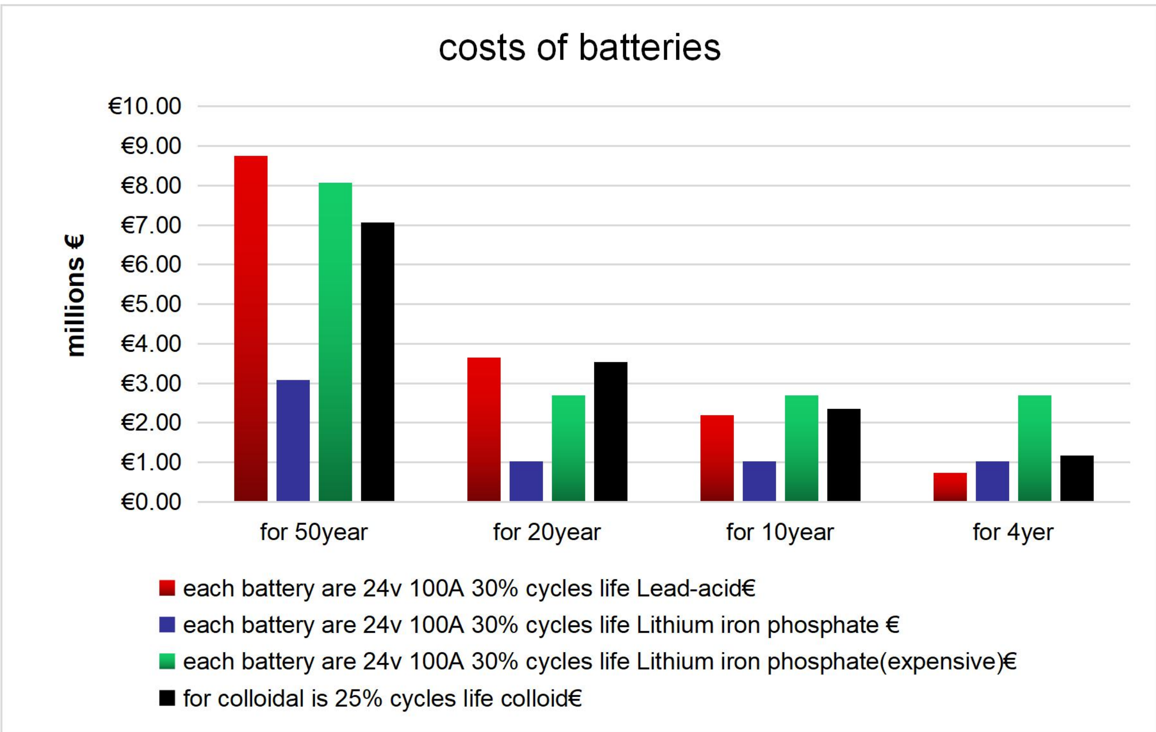


Fig.29

The above figure we choose DOD cycles life between the 30%-50%, because for security of system State of charge (SoC) not be low 25%,it mean is the units of SoC are percentage points (0% = empty; 100% = full).depth of discharge (DoD), the inverse of SoC (100% = empty; 0% = full).so we eliminate of DoD 100%and 80%.by quantity and price we eliminate of DoD 10%.

As can be seen in Figures 28, for 24V and 100 A batteries, normally DOD of 50% are cheaper than DOD of 30 % for all cases except Pb-liquid acid. Only results obtained at 20 years, DOD of 50 % are more expensive than DOD of 30%. In this case, we have to remember that Li batteries are changed after 20 years when DoD of 30% is used. Hence, if you will do the same calculate for 21 years period, DOD of 50 % will be better again. Furthermore, we have to conclude that DOD of 50% usually is preferable for all type of batteries.

The figures below show the economic changes in the three voltage types of the four batteries. We can choose the best battery voltage by analyzing the changes in the graph.

Economic change figure of Pb-Liquid battery between the 12V, 24V, 48V voltage

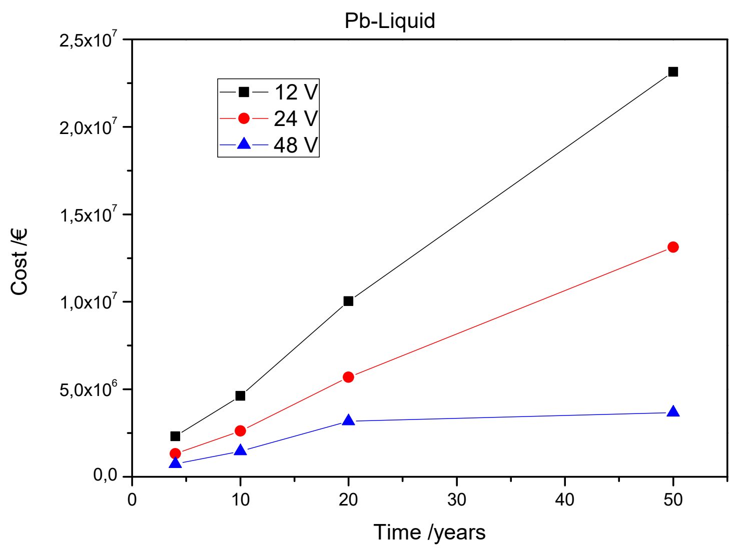


Fig.30

Economic change figure of Li-iron phosphate battery between the 12V, 24V, 48V voltage (cheaper)

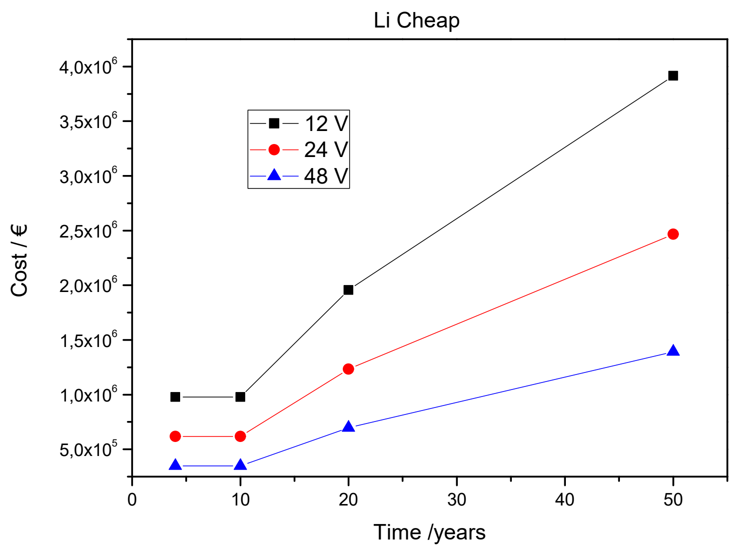


Fig.31

Economic change figure of Li-iron phosphate battery between the 12V, 24V, 48V voltage (expensive)

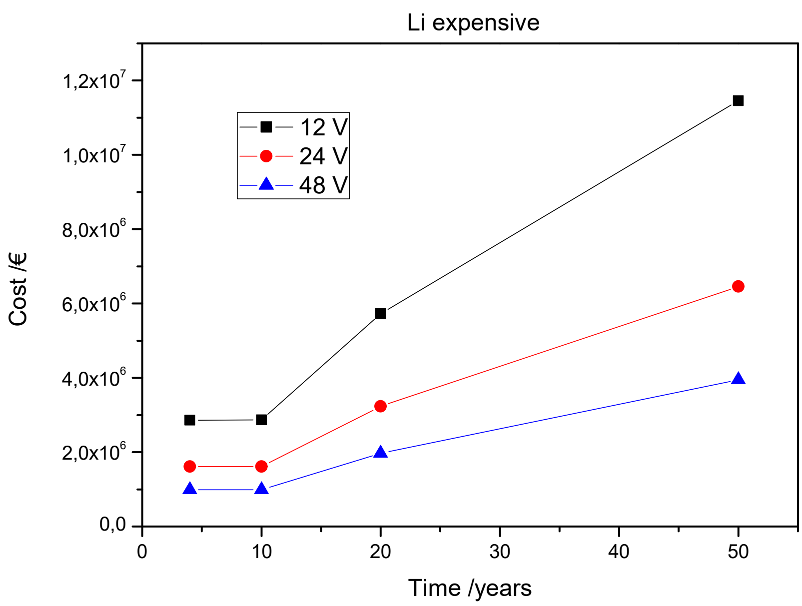


Fig.32

Economic change figure of Pb-colloid battery between the 12V, 24V, 48V voltage

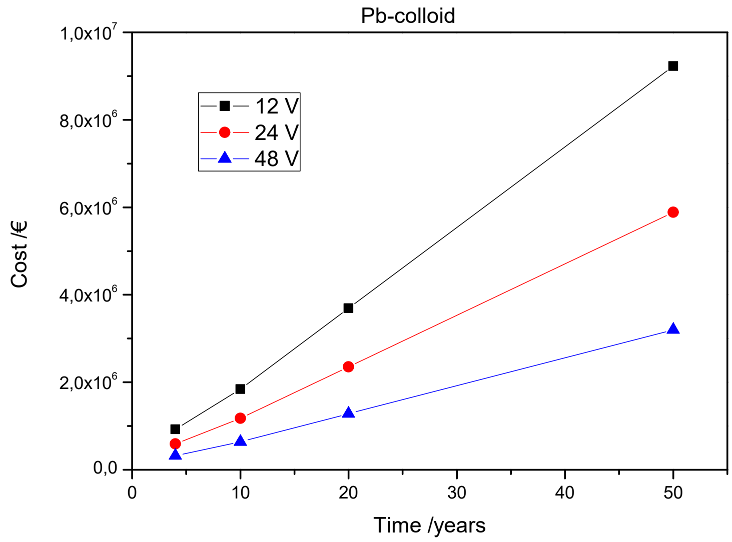


Fig.33

Analyzing these results we can deduce that the cost feedback is better increasing the battery voltage used in the battery packs. Thus, 48 V batteries are the best option to be used. However, there are several cons to use 48 V batteries in the photovoltaic plants. This is the reason because we will analyze in depth the results obtained for 24 V battery packs.

In all voltage battery packs, Li “cheap” batteries seem the best option. However, we have observed that the price of this battery is excessively low compared with other company’s costs. Furthermore, when we have considered the price of a more expensive Li-ion battery (Figure32) we can observe that Pb-colloid is the better option. In conclusion, Pb batteries are still the better option if the Li-ion batteries maintain elevated prices.

Charge controller

An MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries.

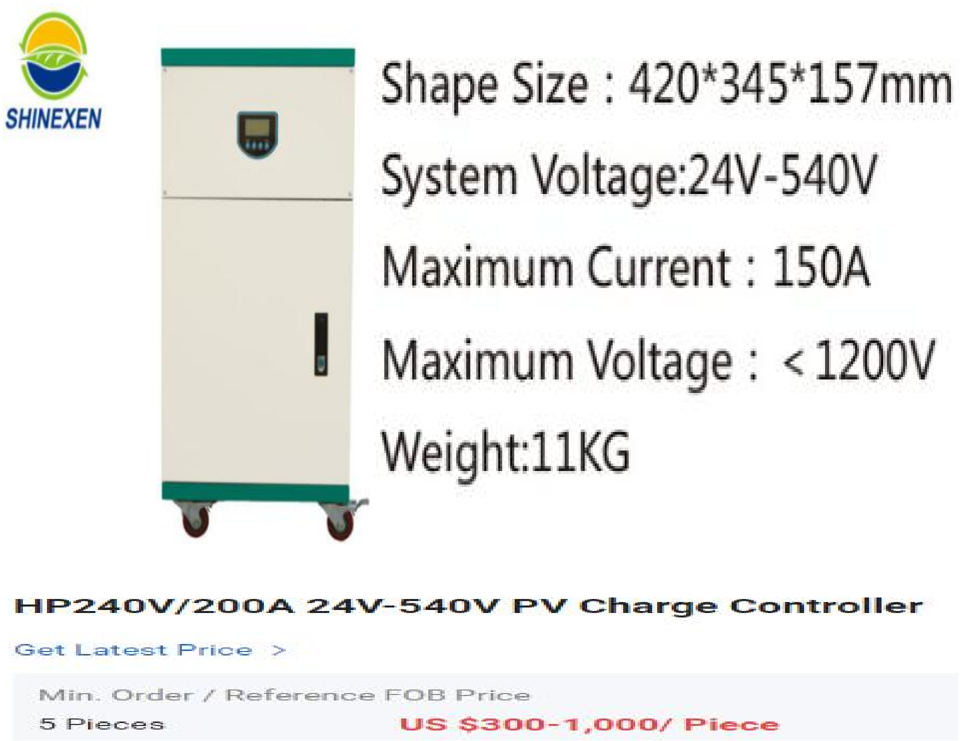
In our PV system I = 8.33A,I = 9.17A, Vmp = 36v, Voc = 43.2v,Pmax=300w

PV arrays are :24parallel,28series

I = 24×9.17A ≈ 220A, 28×43.2v ≈ 1210v

Our target battery (Lithium iron phosphate battery→ 48v,100Ah) .

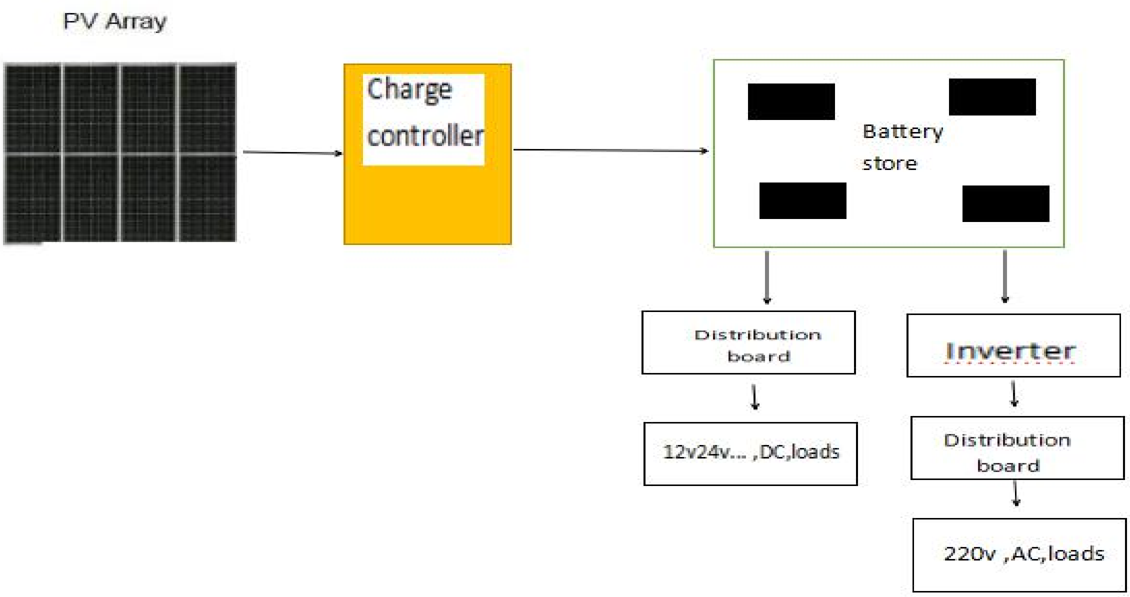
Appropriate charge controller



[38]

Connection scheme

The scheme shows that photovoltaic panels are connected to the charge controller, the controller connected to the battery store, two lines from the battery connected to inverter and distribution board.line from the inverter connected to AC load system and other lines from the distribution connected to DC load system.



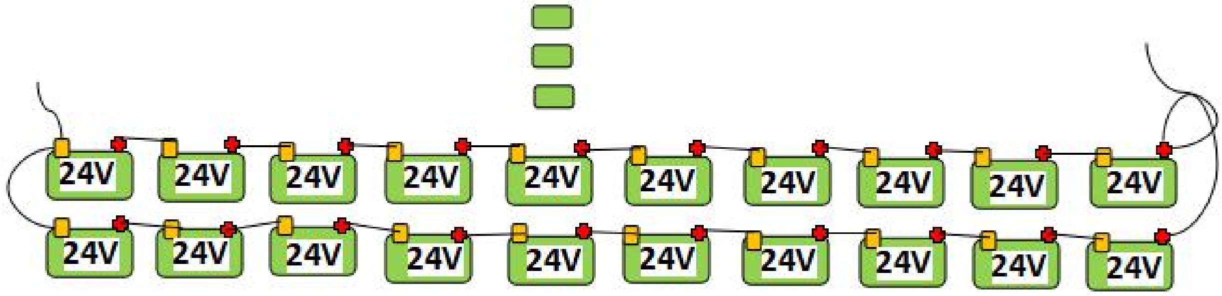
Scheme.1

Connection panels: in our PV system total panels are 674, they connected 24parallels and 28series.

Connection batteries: our target battery is Lithium iron phosphate battery for this system we use to 7956batteries.

for 240v connect 10 batteries series, 9 parallel make a group total 88.4≈89group.

they connected scheme:10 batteries make one group connected series other series groups connected to parallels. use parallel wiring to increase current (power). use series wiring to increase voltage. Use series & parallel wiring in combination.



Scheme .2

Additional design

Battery room

Provide points and protect batteries and electrical equipment for safety We need to build a battery room. the number of batteries we have selected is 1988, Its size is 325x170x220 mm, weight 28kg. Design a shelf with four floors. Put two horizontally, Length put 20. One shelf can hold 80 batteries.

Total battery are ≈ 2000 ÷ 80 = 25.

The shelf we need are 25.Shelf width:70 ㎝;height:1.20m;length:5m.battery shelf area:87.5 ㎡;for other other equipment:4.5 ㎡,Separation distance from each shelf:40 ㎝.for total eras 100 ㎡.

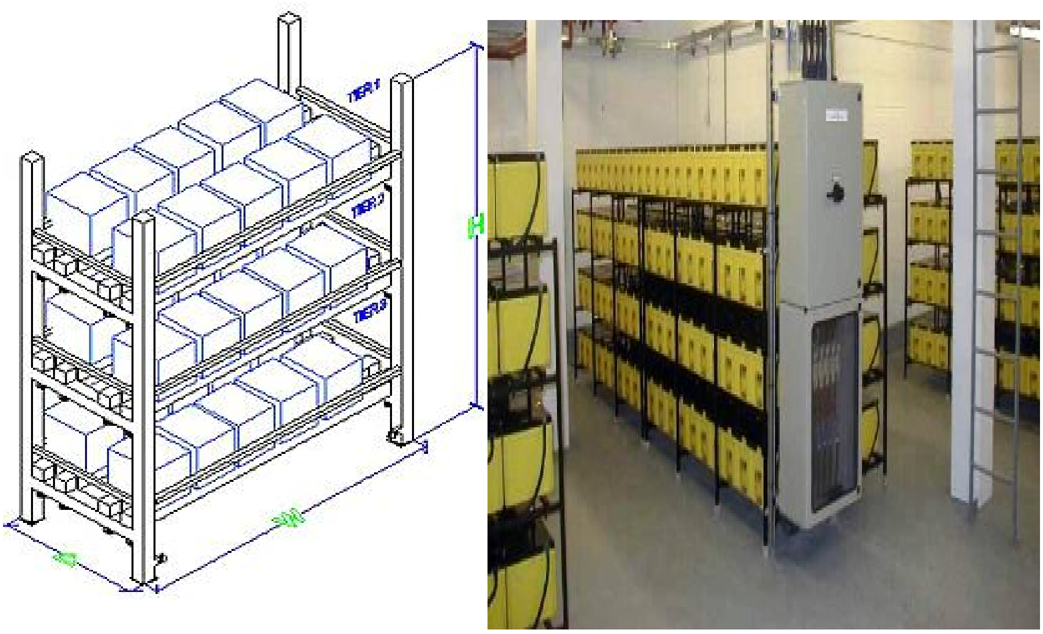


Fig.34.[39]

Heating system

In winter the project area is relatively cold.in the winter than area average minimum temperature: -15℃, Extreme minimum temperature:-27.7℃. The operating temperature range of our target battery is working temperature: charging: 0℃~ +45℃; Discharge: -20℃ ~ +60℃. so we need a heating system for our battery room.

In order to save investment and energy, we use Electric oil heater DYT-Z2.

Fig.35.[40]

Pioneer heater model: DYT-Z2

Applicable area: 21-30 ㎡

Electric heater maximum power: 2000W or more

Maximum heating area (m2): 20m^2 and above

Gear position: 3 files

Heater heating method: oil type

price:269￥

Its heating range is 21-30 ㎡,five Electric oil heater DYT-Z2 enough to heat our battery room.

Investment

Acceptance or rejection of projects is mostly based on economic evaluation. The economic analysis should consider what kind of inputs will enter into a project and what else may affect the value of the project.

All prices in the case study are given in YUAN (￥) but fully reflected prices in Hami Tianshan. Used convert of yuan to the euro was 1 € = 7.75 ￥.

The investment includes all costs connected with the project in the zeroth year, before putting the system into operation. These costs are projected documentation, purchase prices of equipment, transportation of equipment and construction works. All investment costs are shown in the following table.

The 50 years	single cost€	Quantity	Change time	total cost €
project documentation	5810	1	-	5810
PV panels	97	674	2	130756
battery banks	155	15912	-	2466360
transport	0.015€/kg	606942 kg	-	9104.13
construction	120000	1	-	120000
others	5800	1	-	5800
inverter	1100	1	2	2200
charge controller	348	1	2	696
			total investment	2740726.13

Tab.28

The 20 years	single cost€	Quantity	Change time	total cost €
project documentation	5810	1	–	5810
PV panels	97	674	1	65378
battery banks	155	7956	–	1233180
transport	0.015€/kg	312570 kg	–	4688.55
construction	120000	1	–	120000
others	5800	1	–	5800
inverter	1100	1	1	1100
charge controller	348	1	1	348
			total investment	1436304.55

Tab.29

The 10 years	single cost€	Quantity	Change time	total cost €
project documentation	5810	1	–	5810
PV panels	97	674	1	65378
battery banks	155	3978	–	616590
transport	0.015€/kg	91956 kg	–	1379.34
construction	120000	1	–	120000
others	5800	1	–	5800
inverter	1100	1	1	1100
charge controller	348	1	1	348
			total investment	816405.34

Tab.30

The 4 years	single cost€	Quantity	Change time	total cost €
project documentation	5810	1	–	5810
PV panels	97	674	1	65378
battery banks	155	3978	–	616590
transport	0.015€/ kg	91956 kg	–	1379.34
construction	120000	1	–	120000
others	5800	1	–	5800
inverter	1100	1	1	1100
charge controller	348	1	1	348
			total investment	816405.34

Tab.31

Investment benefit conversion

Below we calculate according to the pricing policy of the National Development and Reform Commission.

[In China on December 26, 2016, the National Development and Reform Commission issued a notice for the adjustment of the on-grid price of photovoltaic power stations in 2017. The full text of the WORD version of the policy was released on the 26th. The notice stipulates that after January 1, 2017, the benchmark on-grid tariffs for new photovoltaic power plants in the first to third categories of resource areas will be adjusted to 0.65 yuan, 0.75 yuan and 0.85 yuan per kWh.[41]

consumer	Quantity	demand for a day(kwh)	Electricity price kwh/ €	subsidy €	total(€)	Total price a day(€)	for a year(€)
Tourist attraction service club	17	214.2	0.45	0.3	0.75	161	58765
families	118	454.3	0.2	0.3	0.5	227	82855
						Total cost	141620

Tab.32

Investment analysis

Income and interest change

By investment and income, we can calculate when the investment will be earned back.

Analysis for Li-iron phosphate(cheaper)

24v 100A 50% cycles life for 50year

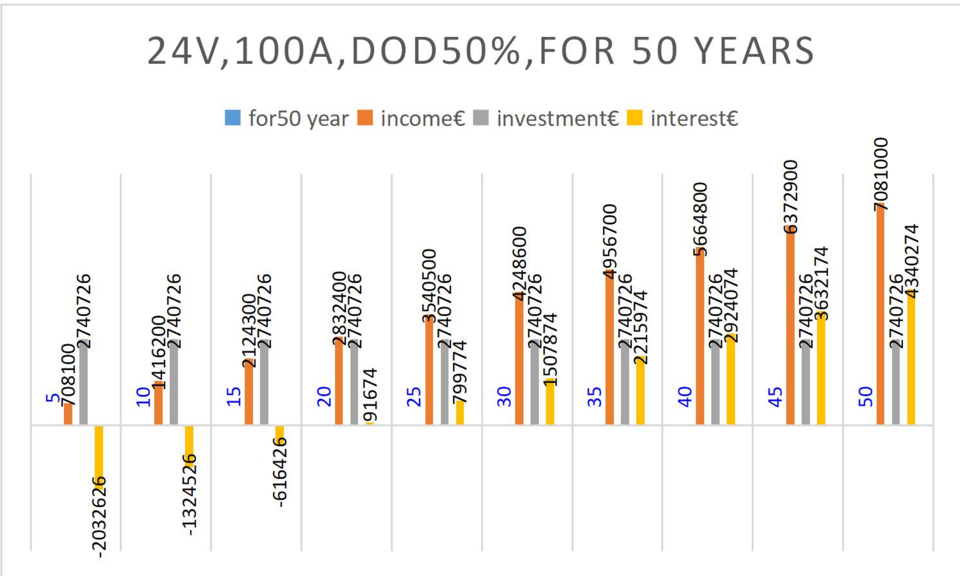


Fig.36

We start earning money at 20 years

24v 100A 50% cycles life for 20 year

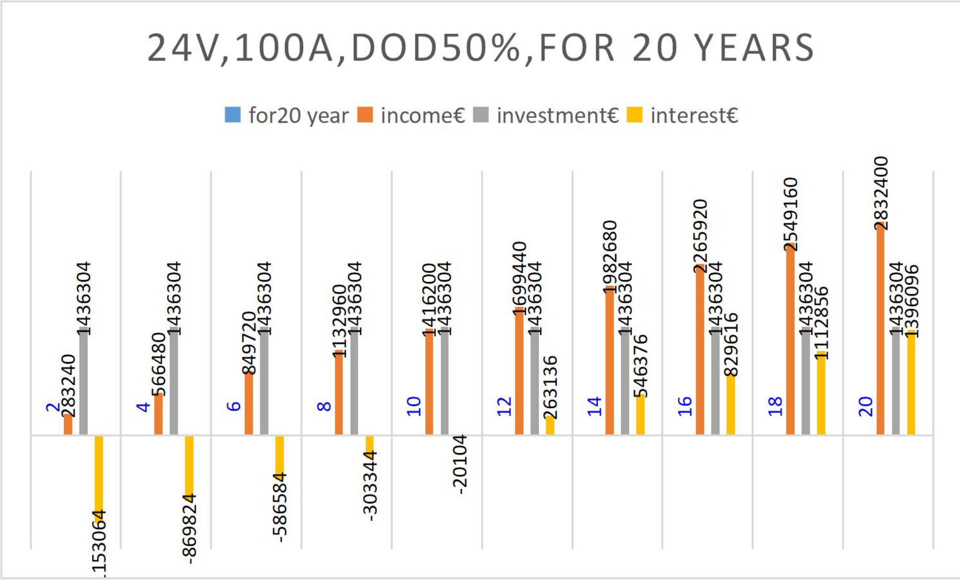


Fig.37

We start earning money at 12 years

24v 100A 50% cycles life 10 year

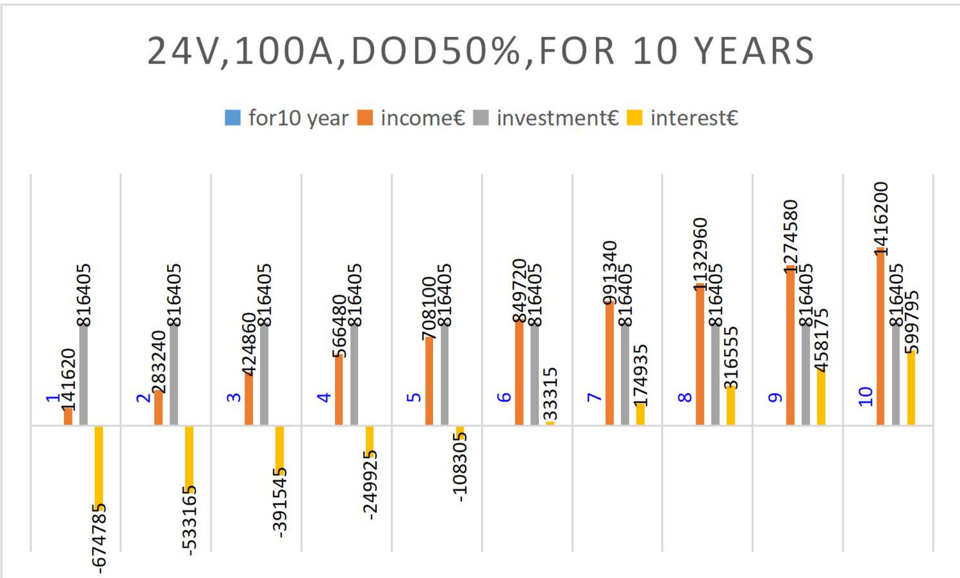


Fig.38

We start earning money at 6 years

24v 100A 50% cycles life for 4 years

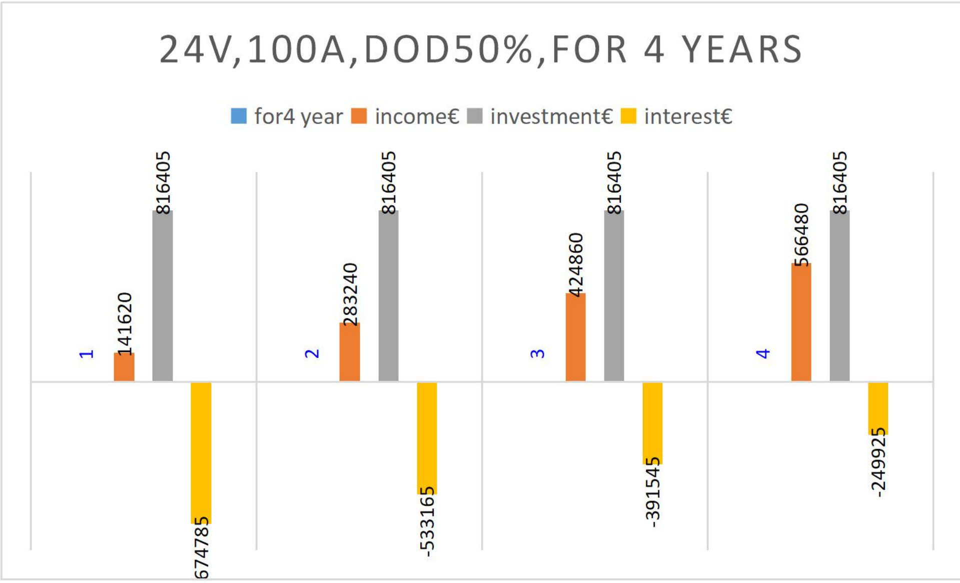


Fig.39

4years not enough to earning money

48V 100A 50% for 50 years

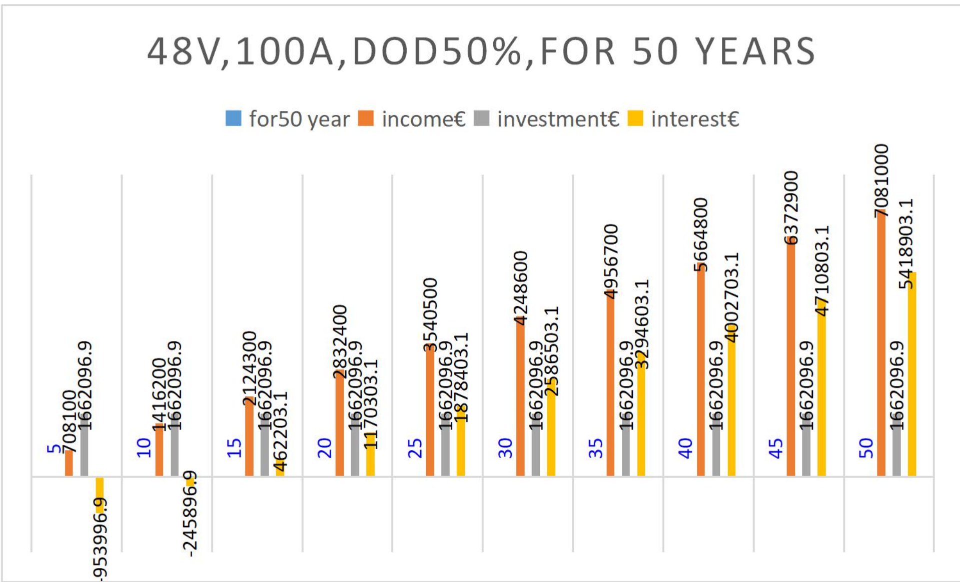


Fig.40

We start earning money at 15 years

48V 100A 50% for 20 years

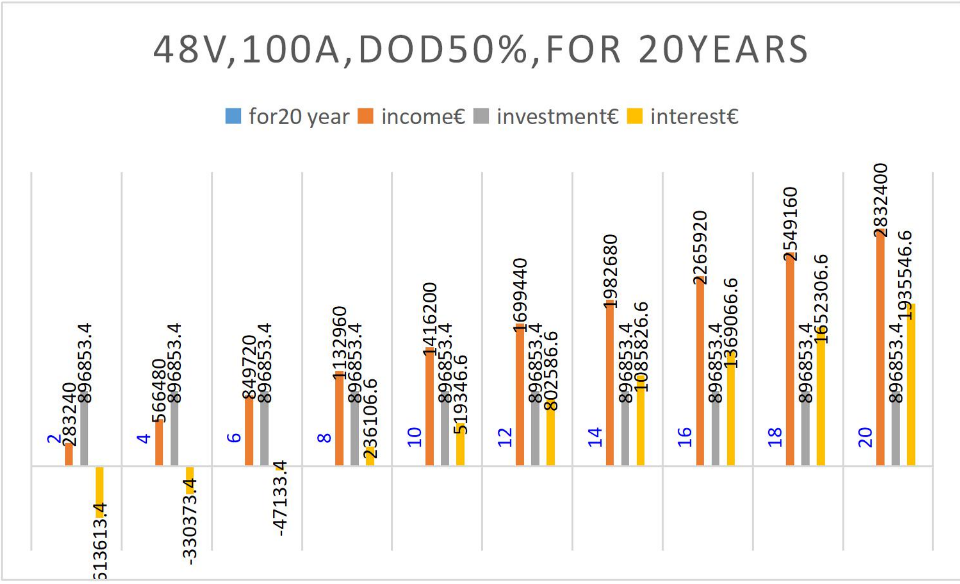


Fig.41

We start earning money at 8 years

48V 100A 50% for 10 years

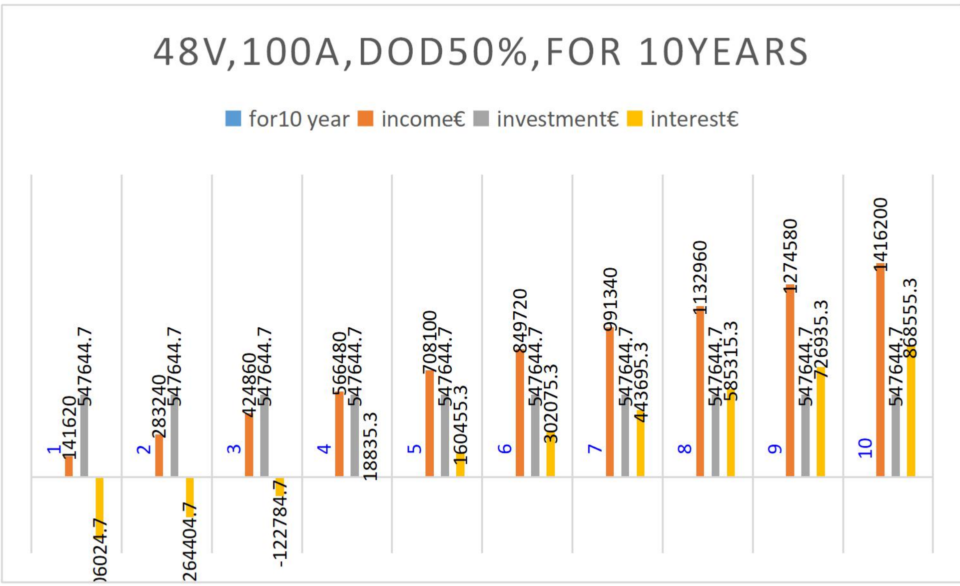


Fig.42

We start earning money at 4 years

48V 100A 50% for 4years

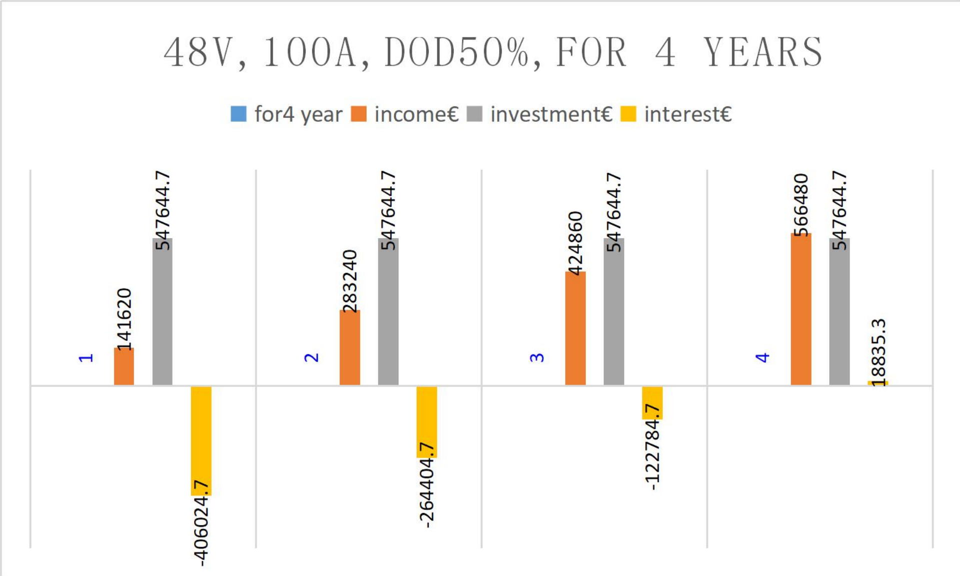


Fig.43

We start earning money at 4 years

24v 100A 30% cycles life for 50year

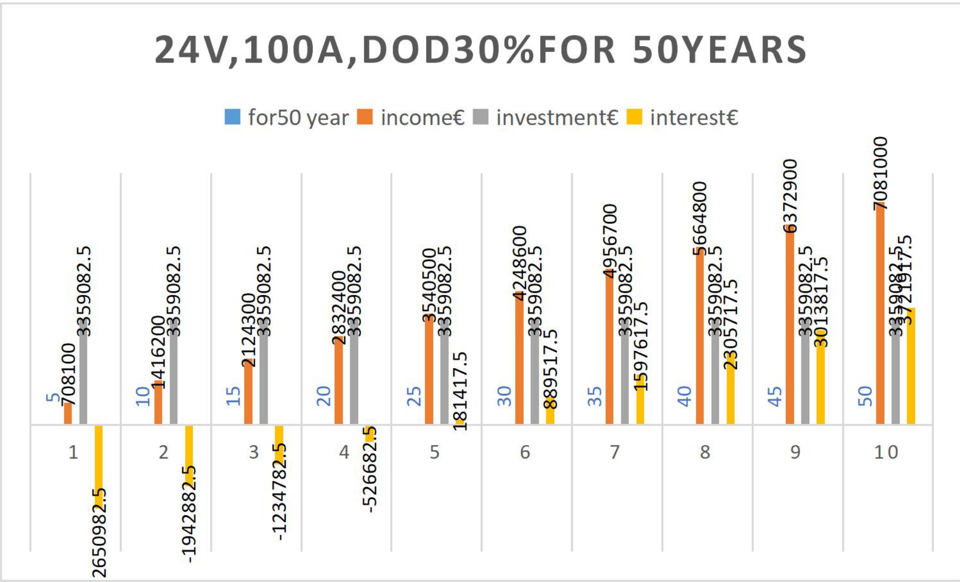


Fig.44

We start earning money at 25 years

24v 100A 30% cycles life for 20year

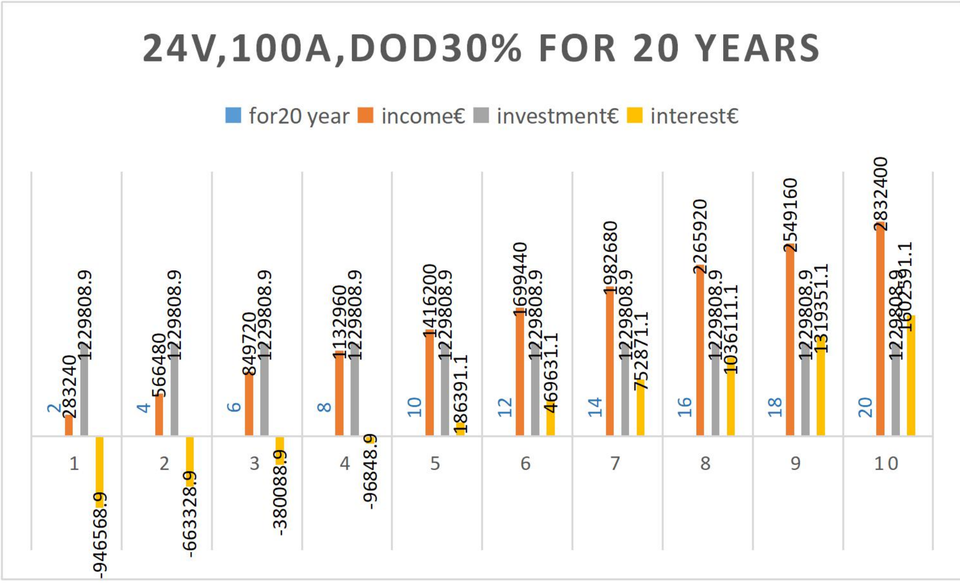


Fig.45

We start earning money at 10 years

24v 100A 30% cycles life for 10year

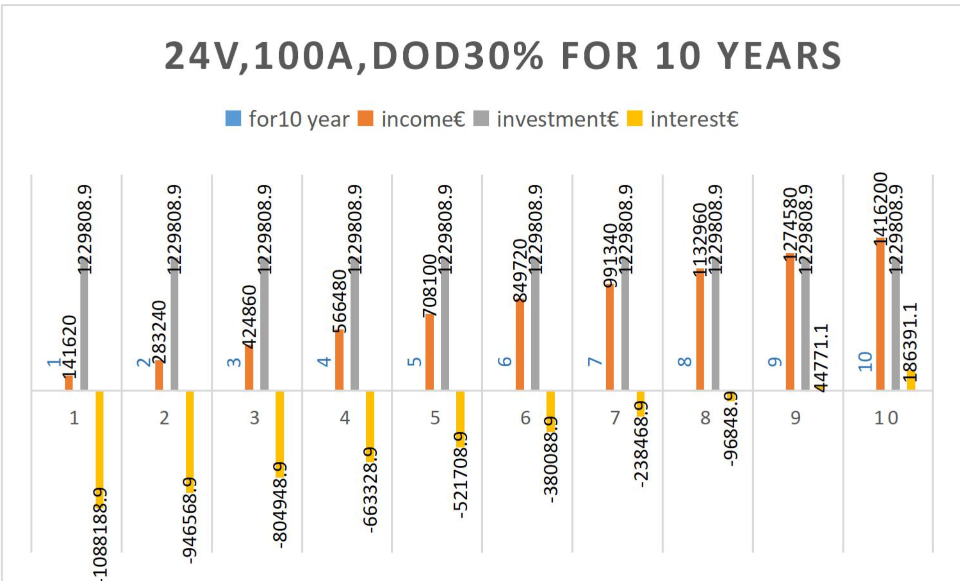


Fig.46

We start earning money at 9 years

24v 100A 30% cycles life for 4year

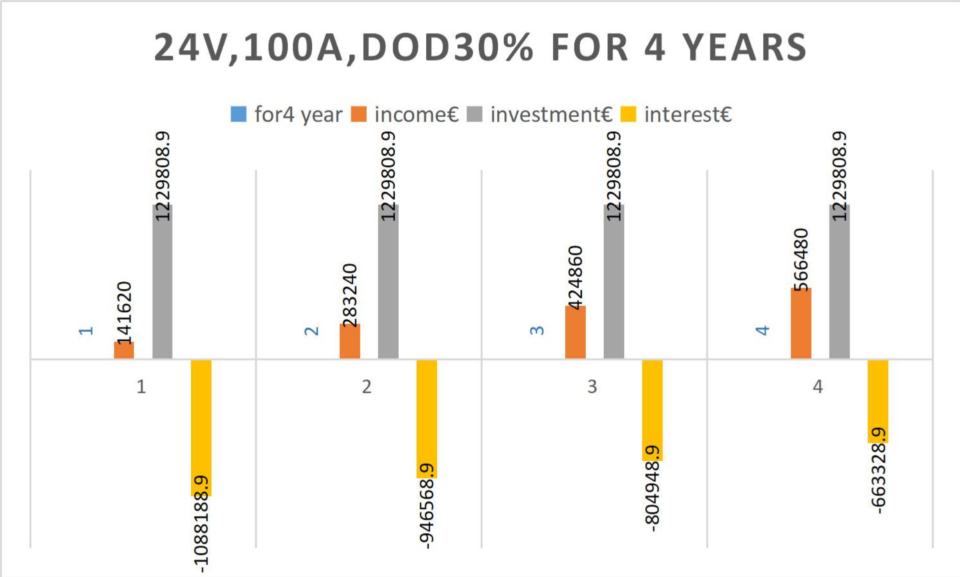


Fig.47

4 years not enough to earning money

48v 100A 30% cycles life for 50year

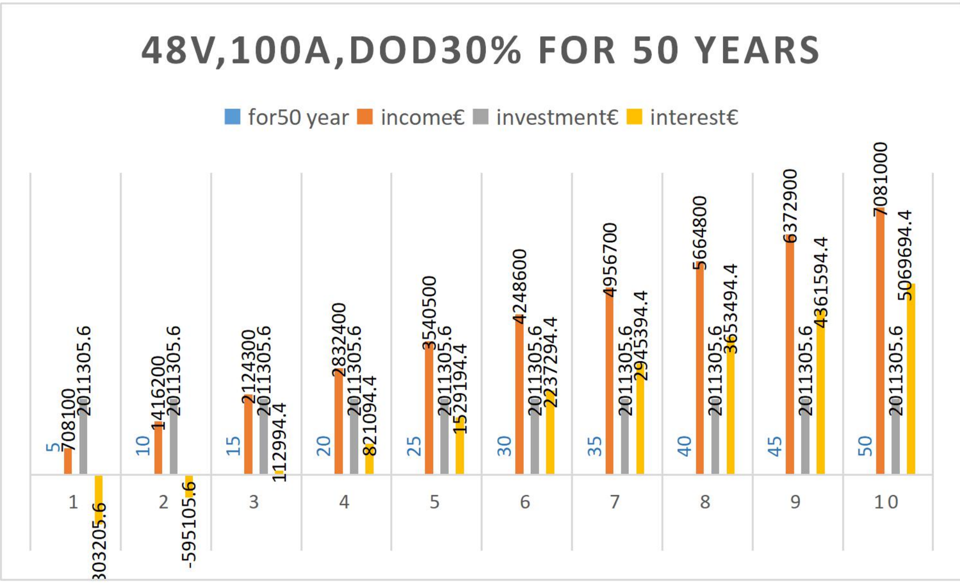


Fig.48

We start earning money at 15 years

48v 100A 30% cycles life for 20year

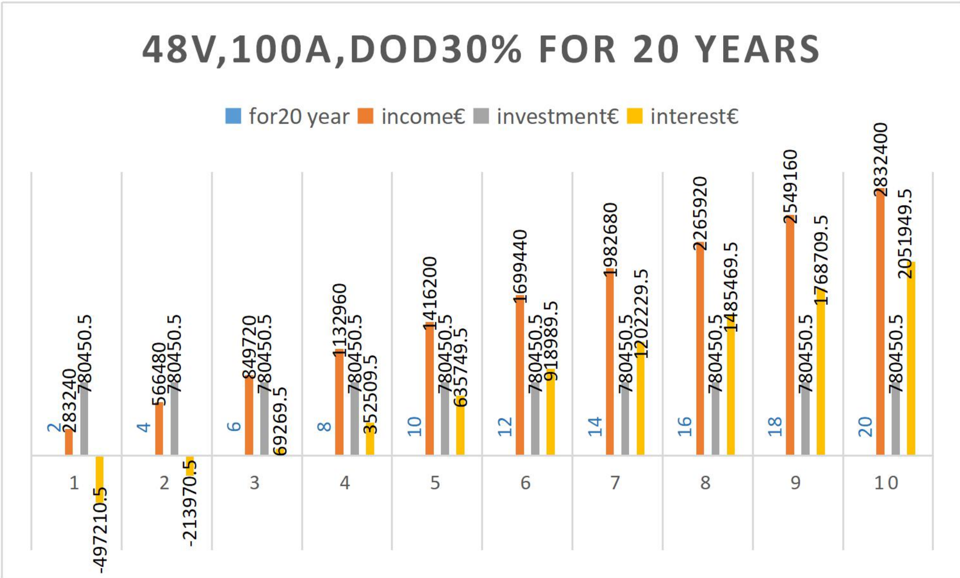


Fig.49

We start earning money at 6 years

48v 100A 30% cycles life for10year

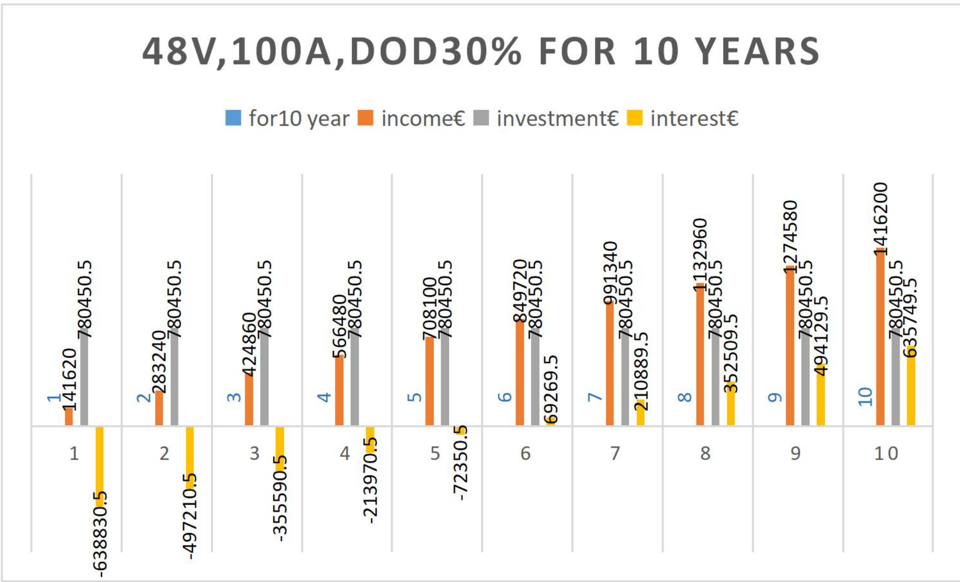


Fig.50

We start earning money at 6 years

48v 100A 30% cycles life for4year

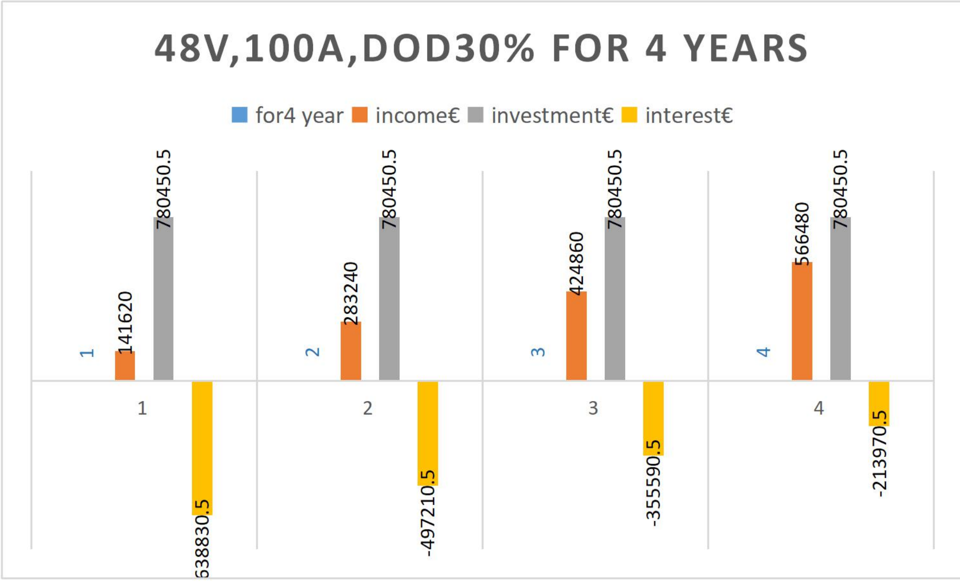


Fig.51

4 years not enough to earning money

Analysis for colloid

24v 100A 50% for 50 years

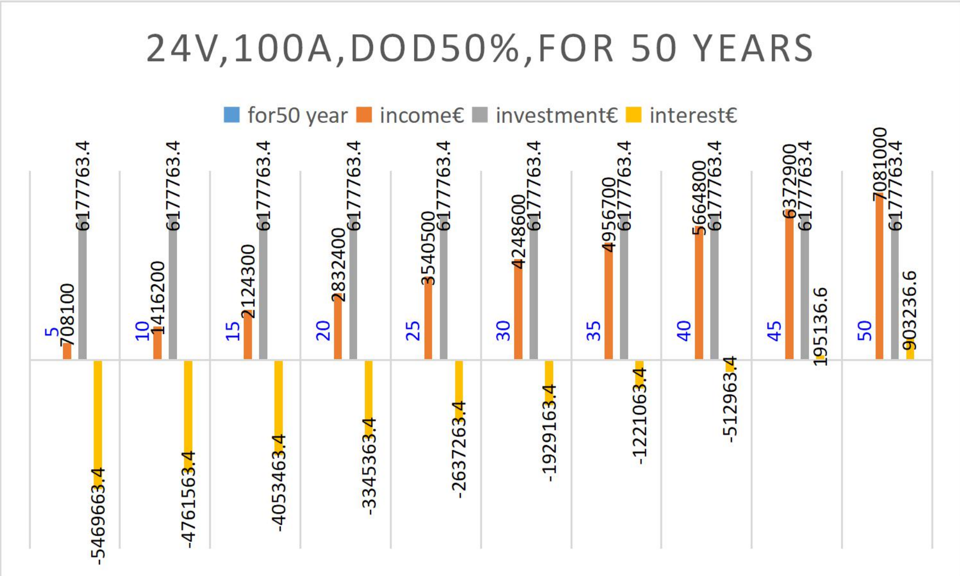


Fig.52

We start earning money at 45 years

24v 100A 50% for 20 years

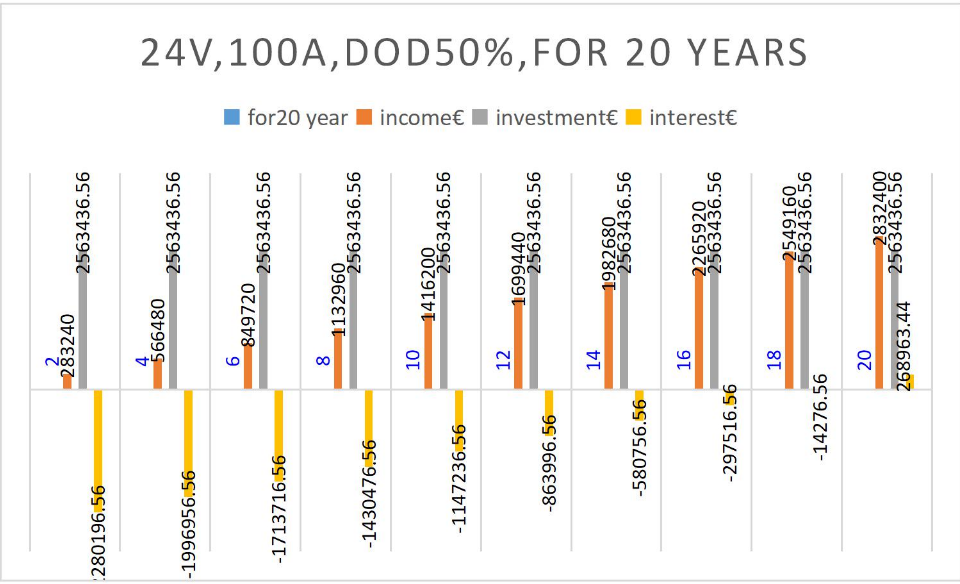


Fig.53

We start earning money at 18 years

24v 100A 50% for 10 years

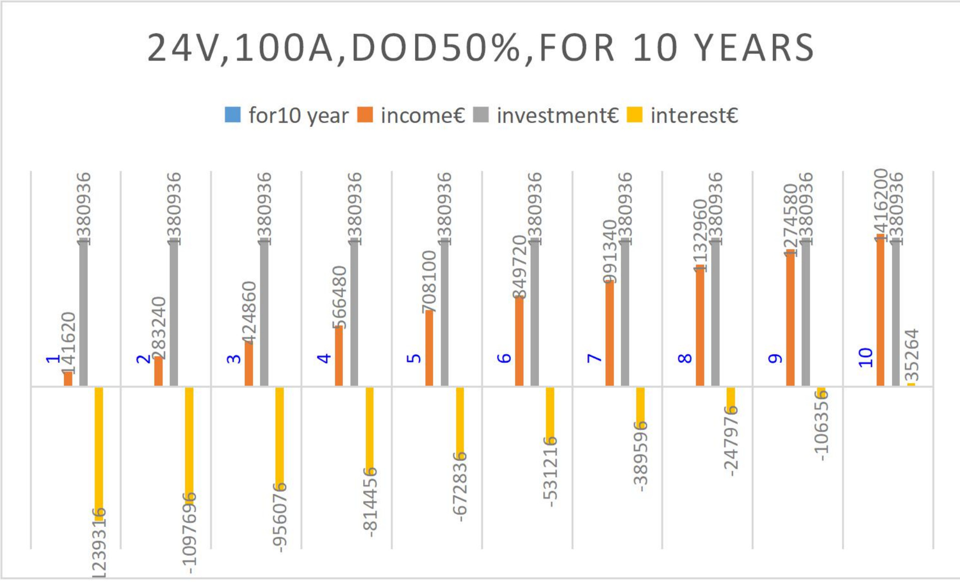


Fig.54

We start earning money at 10 years

24v 100A 50% for 4 years

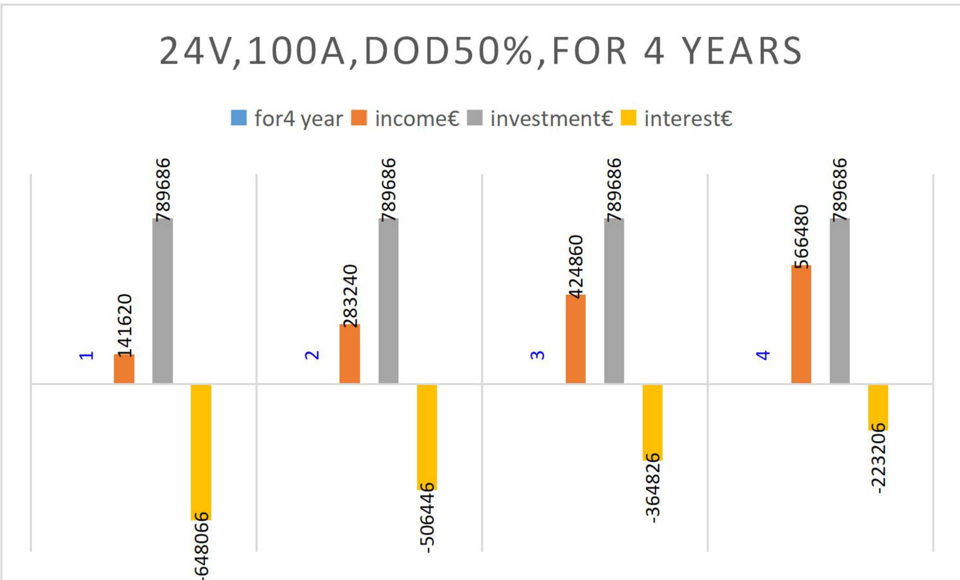


Fig.55

4 years not enough to earning money

48V 100A 50% for 50years

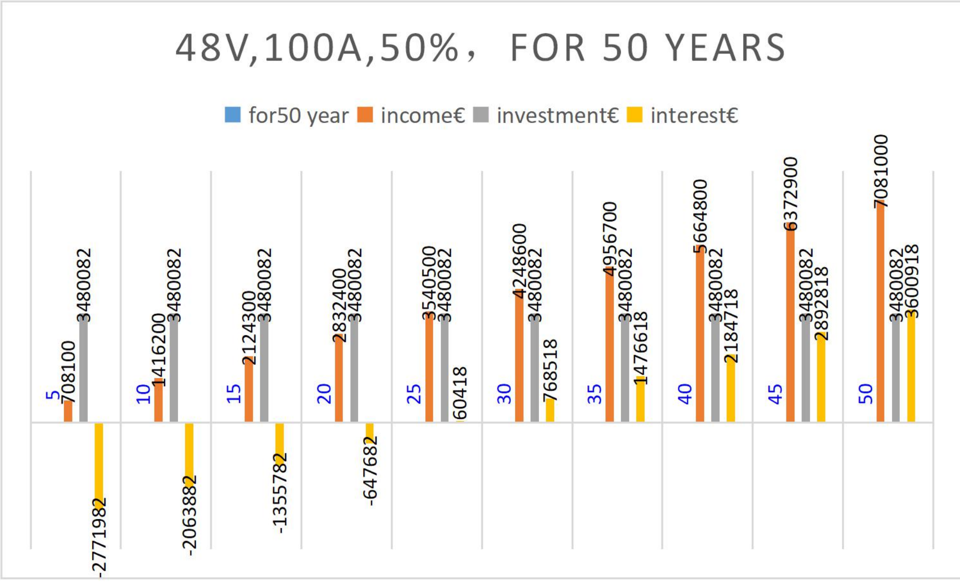


Fig.56

We start earning money at 25years

48V 100A 50% for 20years

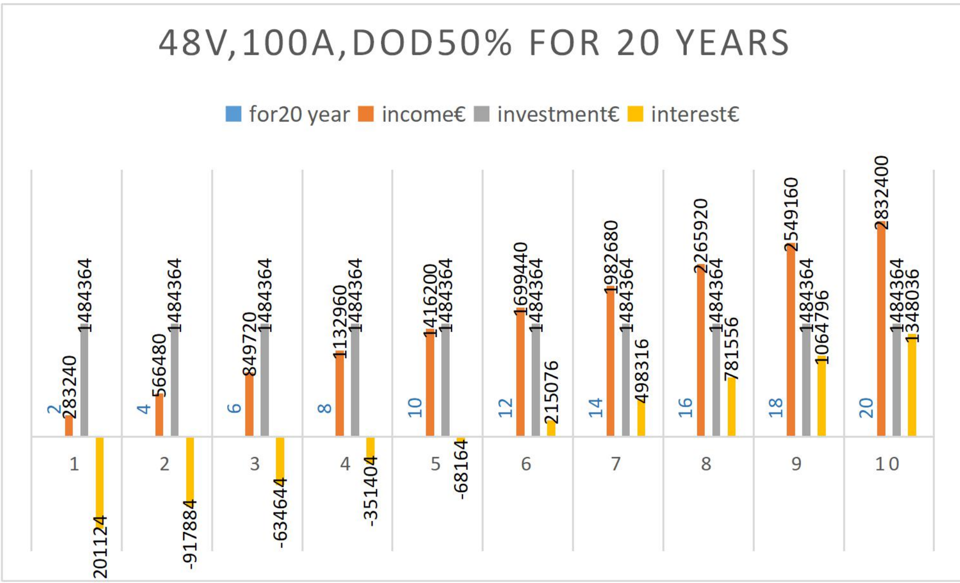


Fig.57

We start earning money at 12 years

48V 100A 50% for 10years

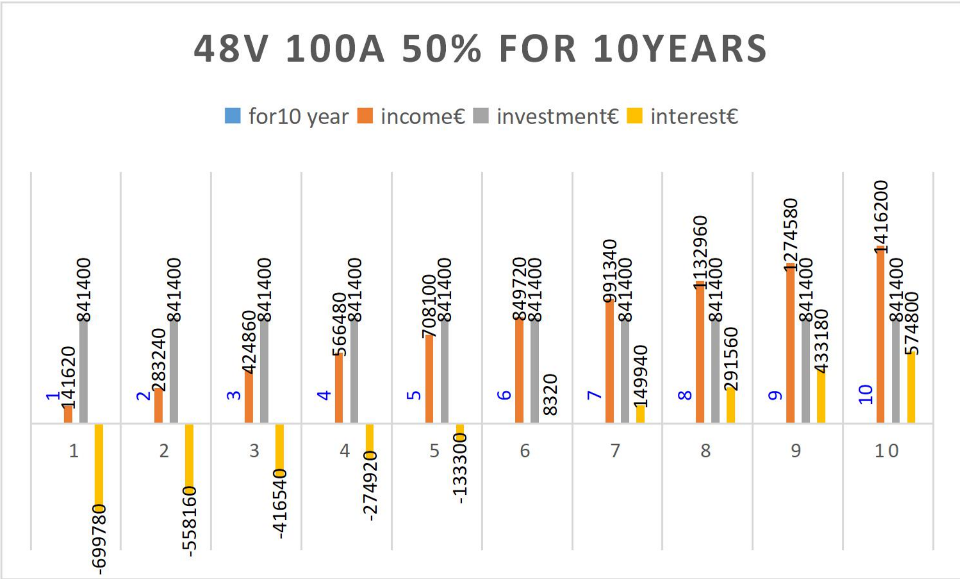


Fig.58

We start earning money at 6 years

48V 100A 50% for 4years

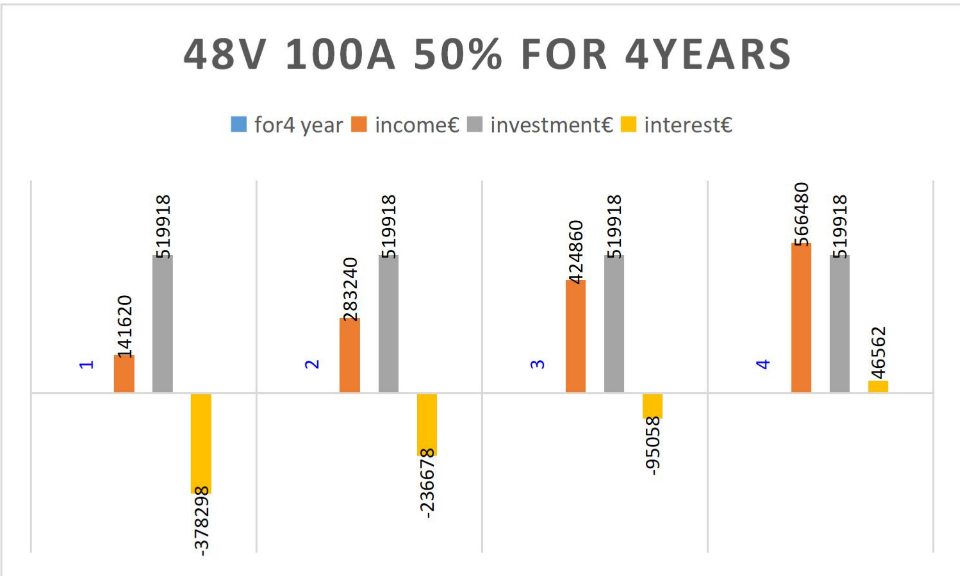


Fig.59

We start earning money at 4 years

24v 100A 25% for 50 years

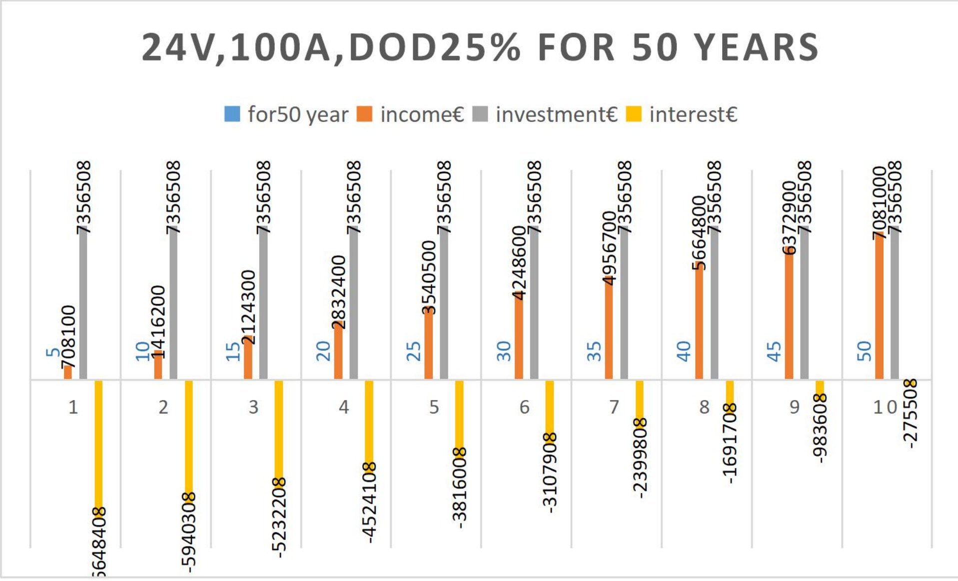


Fig.60

50 years not enough to earning money

24v 100A 25% for 20 years

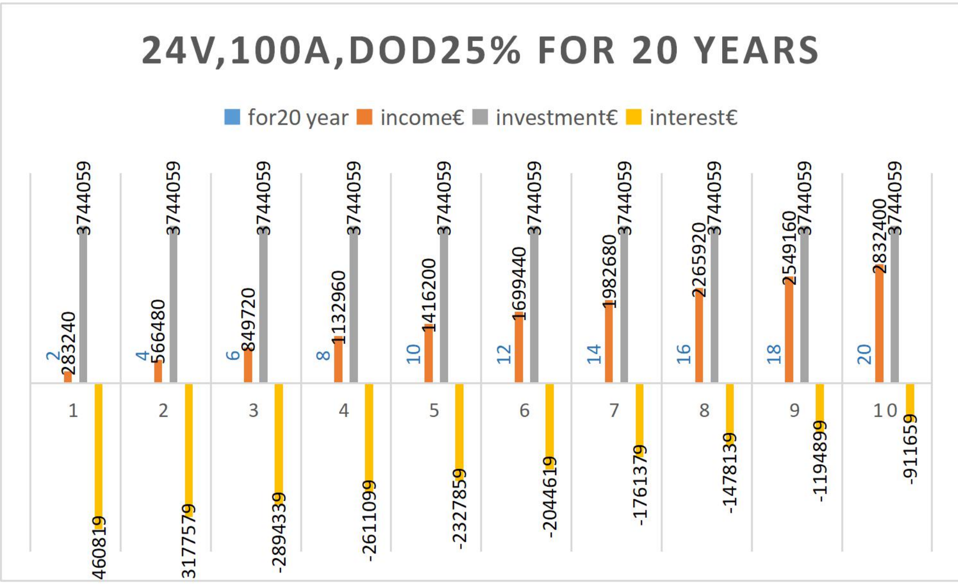


Fig.61

20 years not enough to earning money

24v 100A 25% for 10 years

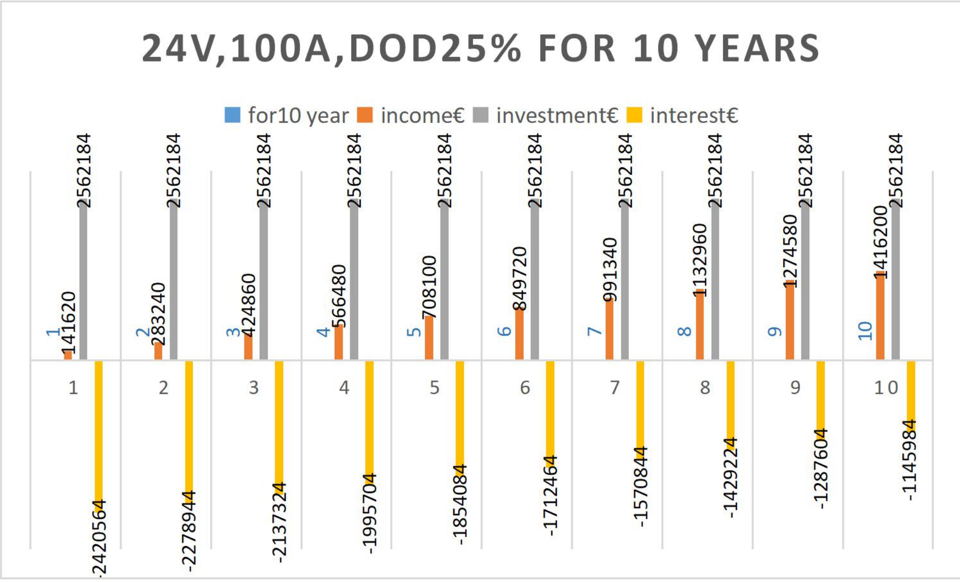


Fig.62

10years not enough to earning money

24v 100A25% for 4 years

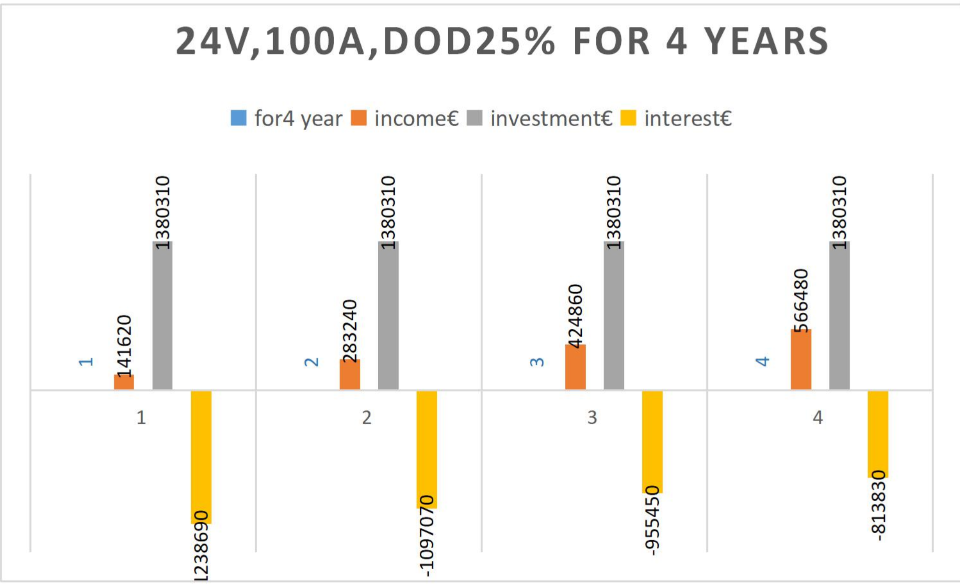


Fig.63

4 years not enough to earning money

48v 100A 25% for 50 years

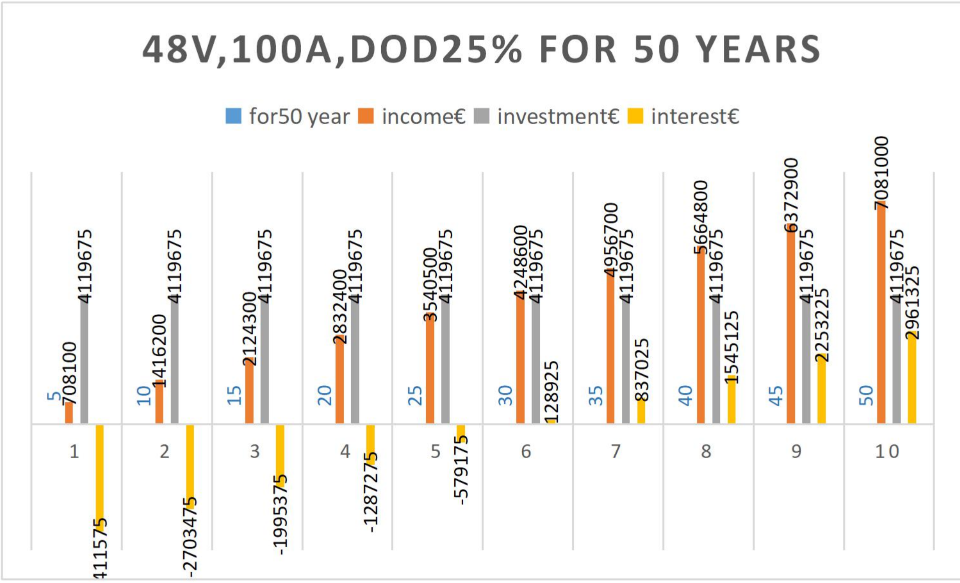


Fig.64

We start earning money at 30years

48v 100A 25% for 20 years

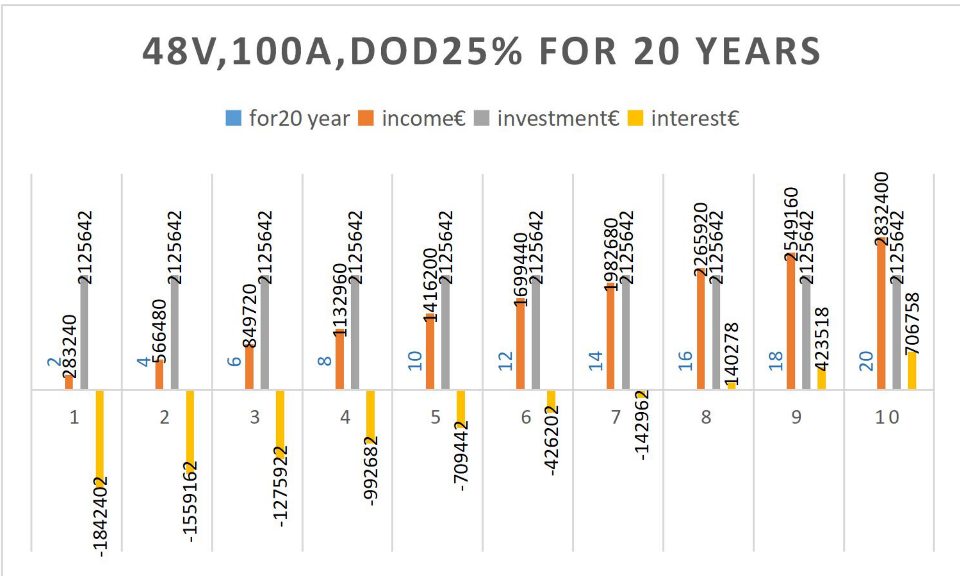


Fig.65

We start earning money at 16years

48v 100A 25% for 10 years

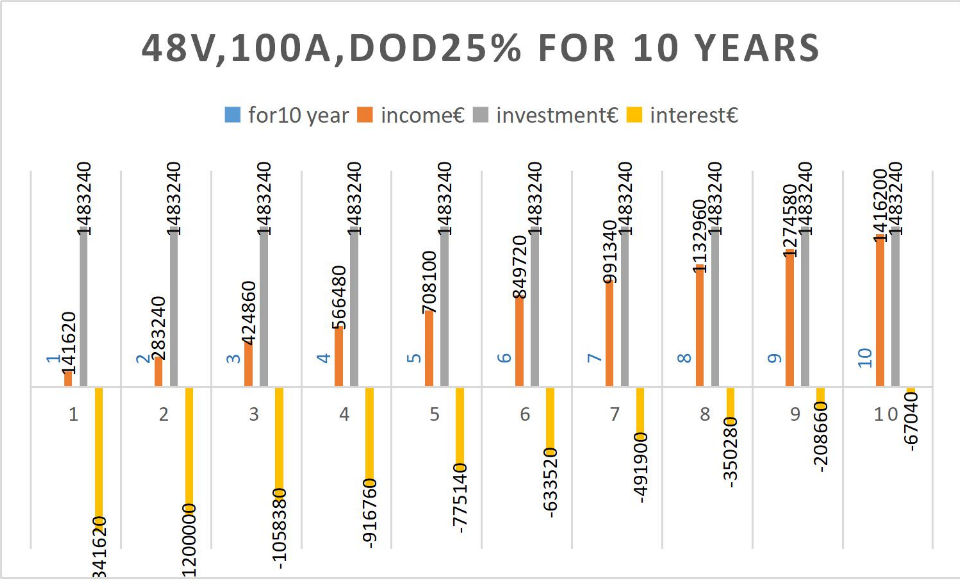


Fig.66

10 years not enough to earning money

48v 100A 25% for 4 years

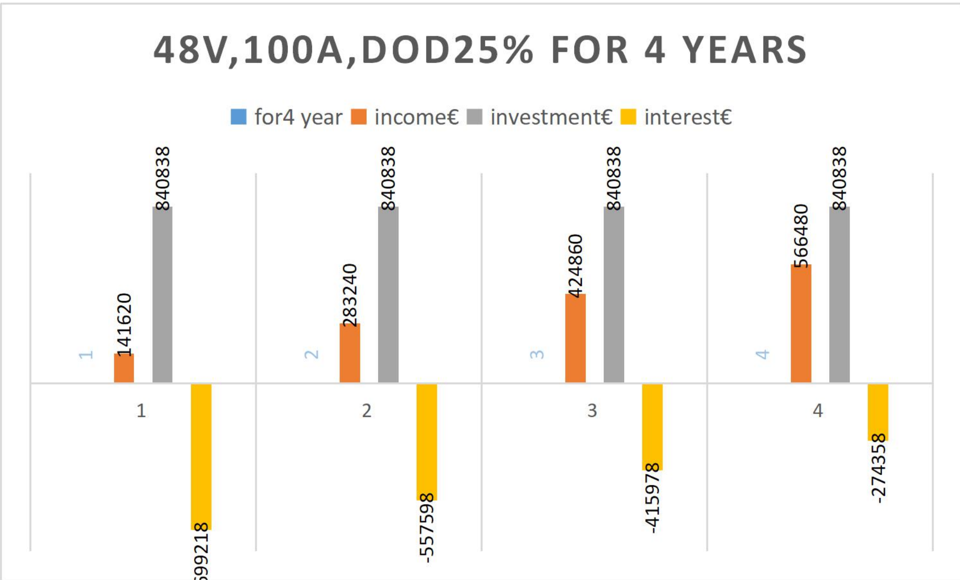


Fig.67

4 years not enough to earning money

After investing and income analysis we can choose the best project time and best invest opportunity.

According to the income analysis, it is not the benefit time that the project with short time like that 10 years and 4 years. and also too long time like 50 year Low economic benefits. the best project time is 20 years because of no need to replace major equipment and have a good income.

Conclusion

The reduction of the earth's non-renewable resources and the deterioration of the natural environment threaten the survival and development of humanity. Using solar cleansing, sustainable green energy can not only meet the growing energy needs of humans but also protect the environment.according to the geographical and climatic conditions of the project area, the most suitable energy supply device there is photovoltaic energy because there is high solar radiation. So we chose to build a photovoltaic power plant there.

To protect the environment, better use of photovoltaic energy has a good understanding of the natural conditions of the project area. Choose the most cost-effective and efficient materials. There is also an analysis of energy demands， design battery field。 to build the most reliable battery field analysis selected four battery samples.

At present, the energy storage device commonly used in photovoltaic power generation systems in the project area is a lead-acid battery. However, it has some insurmountable shortcomings such as short cycle life, low power density, and high maintenance, and the cost of the entire power generation system is high.

(Lead-acid batteries， 24V.100Ah, cycle life DOD 30%-1500time, Final total price:3645950€).

The best project time is 20 years The area actual daily demand is 668.5kW,In order to ensure the demand(120%×668.5kw=802.2kw),802.2kw Is our conversion energy number of panels are 674, Number of Days of Autonomy (N) = 5, ensure the number of batteries required4574.24Here we finally choose battery is Lithium iron phosphate battery Because of its long cycle life, fewer batteries are needed throughout the design time, the investment required is lower. (24V.100Ah,cycle life DOD 30%-8000time,total quantity is 3978,total price 1027495€).

Colloidal battery cycle life than lead-acid battery longer, the investment required is lower than the lead-acid battery. However, It's still a bit worse than the Lithium iron phosphate battery. (Colloidal battery,48V.100Ah,cycle life DOD 25%-3500time,final total price:3532020€).

The main aim of this project is to improve the photovoltaic power plant and the battery bank used in it, choosing the most cost-effective and efficient materials.

In the first step we have carried out an analysis of energy demands，

After that, we have calculated the photovoltaic system and designed a battery bank, analysing four battery kinds.

The investing and income analysis using Li-batteries report that The best project time is 20 years.

Short times, like 4 years, does not have benefits.

Long times, like 50 year, provide low economic benefits, as due to the batteries and the photovoltaic panels have to be replaced more times, increasing the total cost.

Provide points and protect batteries and electrical equipment for safety We need to build a battery room. So design a battery room and the operating temperature range of our target battery is working temperature charging: 0 ℃ ~ +45 ℃ ; Discharge: -20℃ ~+60℃ So in winter, to keep the best work of the battery design a heating measure Can keep the battery working properly.

Final some project information and analysis to see the impact on the development of renewable energy is not only a natural condition but also a relatively significant impact on some technological developments. for example, battery development technology the price of the battery in this project accounts for almost half of the project price. The cycle life of a cheap battery is short But need to be replaced more times Increase total cost. Cheaper battery longer cycle life but still the full price is high. The regular battery use for shorter project time otherwise also left high rate, so we need to improve material of battery In that way, we have developed a new generation of batteries with suitable cycle life. Can reduce the investment in renewable energy applications get clean and cheaper energy.

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