3. The use of optical radiation in the energy sector

In the context of increasing demand for energy, increasing their cost, and environmental aspects of the use of fossil fuels , it is appropriate to use more renewable resources . A direct use of sunlight is offered as it is available everywhere and can be used free of charge . A solar plant can be placed almost anywhere, as close to the consumption as possible is convenient to minimize losses on transmission lines. In accordance with the international obligations of the increasing production from renewable sources, state subsidizes the purchase price of electricity from renewable sources.

After 1839, French physicist Becquerel dealt with the first experiments in which the photoelectric effect was observed . The photovoltaic cell was based on metal electrodes immersed in an electrolyte. The development of the first solid article is attributed to Adams and Daym who produced it from selenium in 1877. Fritts´ article (1883) had already the efficacy of about 1%. The further development of PV technology was influenced by theoretical clarification of photoelectric effect by Albert Einstein, for which he was awarded the Nobel Prize in 1921. The modern technology of silicon cells was a significant discovery method production of pure single crystal silicon , developed by Jan Czochralski .

The first applications of PV panels as an energy source was cosmonautics- PV panels have been the ideal power source for satellites. Commercially , the PV cells first started to be used as an energy source for miniaturized electronics (calculators, watches). The oil crisis in 1973 was a strong impulse for solar energy development. It started the process of more efficient production and use of energy resources. Almost like an avalanche , the PV systems have been developing in recent years, due to grant programmes, which caused great interest of investors in this area of electricity production. Everything indicates that renewable sources of energy (and thus PV systems) are essential for maintaining the current development of human civilization in the future.

3.1. Solar radiation

Solar radiation is one of the cleanest and most affordable source of energy on the Earth. The Sun is the source of radiant energy in the entire spectral range from the smallest wavelength of X and ultraviolet rays to radio radiation of meter lengths. Light and Infrared radiation of the of wavelength 0.2 micron to 3 microns is the most frequent (the human eye perceives radiation in the range from 0.38 to 0.76 mm). The weight of the Sun is some 330,000 times greater than the weight of the Earth and it is 99.8% of the weight of the solar system.

Tab. 3.1 : The energetic distribution of the solar constant - the most of energy falls in the form of visible light

The source of solar energy, as its name suggests, is solar radiation . The Sun, our nearest star, 150 million kilometers far from the Earth, is composed of 75 % of hydrogen and 25% of helium, the age of the Sun is estimated to 4.6 billion years. Thermonuclear reactions converting hydrogen into helium have been proceeding in the Sun continuously, with 4.26 million tons of the Sun weight lost every second. The Sun radiates the energy of this loss to the surroundings - per second it is 3.8 · 1026 J. The Sun will shine next 5 billion years. The temperature of the Sun surface is 5770 K, so maximum radiation can be found at a wavelength of 555 nm, which people sense as yellow (although most of its radiation is in the green part of the visible spectrum).
The Sun diameter is about 1.4 million kilometers , which is about 109 Earth diameters . Its extent is therefore probably 1.3 million times greater than the extent of the Earth. The average density of the Sun is 1400 kg m - 3. The Sun is a sphere of hot plasma which constantly produces huge amounts of energy. Its output is about 4 × 1026 W , about 45 billionths hit the Earth . Approximately a half of the radiant flux of the Sun is absorbed by the Earth's surface and is then radiated in the form of IR radiation in universe. A large amount of energy is consumed to evaporate the water in the oceans.
The energy of the sun is at its core , which consists of three parts (Figure 3.0):

- core
  the thermonuclear reaction takes place (temperature 13106 K)
- Region of the atmosphere
  the emergence of electromagnetic radiation (photosphere , chromosphere => corona)
- Solar wind
  protons , α particles and electrons emit

Fig. 3.0: Composition of the Sun

Only a fraction of this energy - one two-billionth hits the surface of our atmosphere. The incident radiant energy has a value of 1.37 kW · m-2 and this value is called the solar constant. Its size in time changes slightly depending on changes in solar activity spots (in 11-year cycles) and the actual distance of the Earth from the Sun (the movement is slightly elliptical).

Fig. 3.1: The spectral composition of light reaching the Earth

Our atmosphere has a filtering effect - causes a decrease in the intensity of radiation, especially in shorter wavelengths - ultraviolet. Therefore the maximum solar power E = 1000 W · m-second falls on the surface of the Earth when it is nice weather around noon. This value is almost independent of the location and at the equator it is only slightly higher. The total luminosities of 180,000 TW turns on the Earth surface illuminated by the Sun .

Decrease of radiation is also dependent on the angle of the incidence of rays, thus the thickness of the atmosphere they have to pass. Therefore, so-called AM (Air Mass Factor) is used - an optical thickness of the atmosphere, expressing multiple thickness of the atmosphere that the light has to pass. AM = 1.5, which corresponds to the sun angle of 41.75 °, is commonly used for calculations and measurements.

Approximate calculation of the optical thickness of the atmosphere (neglecting the curvature of the Earth):

AM = (1.1)

where φ - is the angle of the sun's height above the horizon

Other factors affecting the impact of radiant energy on the Earth include the elevation (radiation passes through a thinner layer of the atmosphere), air pollution (causes dispersion or may absorb radiation) and last but not least, the clouds.

FIG. 3.2: The values of AM for the position of the sun in the sky

We distinguish between direct and indirect exposure, the sum of which gives the total exposure. Direct exposure prevails when the sky is clear and cloudless; when passing through clouds the light disperses and the radiation of the Earth is indirect. About one-half of the energy fallen in the Czech Republic every year is in the form of direct radiation and the other half is diffuse radiation.

Solar radiation can be divided into two components:

- Direct sunlight (IP)
- Diffuse solar radiation (ID)
  - the terms of the light scattered by the reflection of gas molecules and dust clouds
  - intensity of diffuse radiation increases by the contamination factor (Z)

The theoretical amount of energy incident per unit time per unit area outside the Earth's atmosphere is called the solar constant Tab.3.1 and its value is approximately I0 = 1360 W.m-second. The measure of reducing the intensity of this radiation is so called pollution coefficient Z, which depends on the content of impurities and atmospheric pressure. Characteristic values of the pollution coefficient are listed in Table 3.1.

The intensity of direct solar radiation incident on a surface perpendicular to the beams (IPN) can be described by equation (1.2).

IPN = I0 . A- Z (W.m -2) (1.2)

For the generic area then:

IP = IPN . cosg (W . m -2) (1.3)

where γ- the angle of the sun's rays

The theoretical amount of energy incident on the lighted area per day is dependent on the slope of collector α and pollution coefficient Z. The optimum angle for maximum solar radiation changes during the year as follows :

· summer

· Summer period 30 ° - 45 °

· Winter period 60 ° - 90 °

area type pollution coefficient Z
places to 2,000 m.n.m. 2.0
places over 1000 m.n.m. 2.5
countryside without industrial grime 3.0
cities and industrial centers 4.0
heavily polluted environment ≥ 5.0

Tab. 3.2: Typical values of the pollution coefficient

On a clear summer day, the proportion of diffuse (indirect) radiation is about 10%, in hazy or particularly cloudy day in the fall or winter it is up to 100%.
Fluctuations in the supply of energy in the annual aggregate are caused especially by the Earth's axis inclination - by circulation of the Earth around the Sun first northern hemisphere is illuminated and then southern hemisphere. In winter, there is less radiation because of the position of the Sun below the horizon and shorter days. The farther we are from equator, the greater the differences between winter and summer half year are.

FIG. 3.3: The share of direct and indirect radiation in the Czech Republic during the year

Total sunshine hours in our country usually range between 1400 - 1800 hours a year. Average annual energy which hits the Earth is about 1,081 kWh · m-2. In our conditions the standard static photovoltaic (PV) system with power 1 kWp is able to produce 900 - 1,000 kWh of electricity per year. Of this amount, 75% during April to October, and 25% the remainder of the year.

FIG. 3.4: Total annual energy incident on a horizontal plane [20]

As seen from the figure, a determinant of an amount of incident radiant energy is latitude. The difference in the amount of incident energy between the place with the best and worst location is about 17%.

3.2. Solar Systems

Solar systems - implementation for the exploitation of solar energy - can be divided into two basic types:
· Passive systems - these are design solutions that help harness the sun potential and reduce energy losses,

· Active systems - are devices or files that are primarily designed to convert solar energy into thermal or electrical energy.

FIG. 3.5: Distribution of solar systems

We shall also examine the production of electricity, which can be done either directly, using solar cells, or indirectly by utilizing heat energy as a means to generate electrical energy.

3.2.1. Photovoltaic systems

Photovoltaic systems are sources of electricity directly from sunlight, where photovoltaic cells are used. A fundamental element and essence of each photovoltaic system is the solar cell. The principle of its function is the photoelectric effect, which was first observed already in 1839 by A. E. Bequerel. Interpreting of its essence, however, was managed to by A. Einstein in 1905. However, only the era of semiconductors and space missions after the World War II meant rapid development for the industry accompanied by increasing of cell efficiency.

3.2.2 Principle of operation of a photovoltaic cell

The basic principle of PV cell is the photoelectric effect, in which electrons are released from the substance by the substance absorption of electromagnetic radiation. The absorption is caused by the interaction of light (photons) with matter particles (electrons and nuclei) and following cases may occur:

· The interaction of the particles with a grid

the use of low-energy photons

· The interaction with free electrons

only an increase of temperature occurs (photothermal systems)

· The interaction with bound electrons

free charge carriers are formed

an electron may be released from the binding

For the function of a PV cell is essential that the photon from solar radiation released an electron in the substance and a couple electron- hole was formed. However, there is their immediate recombination in metals, which has to be prevented and the formed charge taken taken away from the article. For this purpose a semiconductor is used, in which electrons and holes are separated by the internal electric field of the PN junction. The simplest solar cell can be described as a large format diode with one PN junction. In order that the photovoltaic conversion is able to take place the following conditions have to be met:

- Photon must be absorbed ,
- Photon must excite an electron to a higher conduction band
- The formed pair of electron (-) - a hole (+) must be separated in order that it is not reconnected

- Separate charges are then transferred to the appliance.

.

In Figure 3.6 and Figure 3.7 basic principles of the photoelectric effect are displayed.Psi - P type silicon semiconductor , NSi - N - type silicon semiconductor , EC - energy conduction band , EV - energy valence band , Eg - energy band gap

FIG. 3.6: The principle of direct conversion of solar energy into electricity using photoelectric effect [2]

In the irradiated area of the PN junction carriers are generated, which subsequently diffuse toward the PN junction . Current density (JPV) consists of carriers that were captured by the area of space charge (equation 1.4). The current density for each area of the PN junction is defined in equations 1.5 - 1.6 . Carriers generated outside transitions of PN has to region the strong electric field diffuse . If they recombine earlier than they reach the area of PN junction, they will not be used in the generation of photovoltaic power.

FIG. 3.7: Principle of the photoelectric effect [15], [2]

h is Planck's constant (quantum effects) h = 6,626 . 10^{-34} [Js]
n frequency radiation
In Newton's theory light is regarded as the sum of the immense number of photons, each of which has energy equal to quantum E = hn
For the N - type region, the equation is:
Photovoltaic (PV) cell can be modeled by an equivalent circuit, shown in figure (3.8). The irradiated area (area Ailly) of PN junction generates a stream of JPV density (IPV) with the positively charged P - type region and negatively charged N -type region.The transition is permeably polarized in this way and the part of the generated current flows back through diode D.
Technological imperfections (mikroleads) of PN junction are modeled by Rp leakage resistance, the impact of the resistance of material and the current bus is modeled by a series resistor Rs.
The output voltage U on the PV cell is the voltage drop across the series resistance lower than the voltage Uj diode .

FIG. 3.8: Equivalent circuit of a photovoltaic cell [15], [2]

Based on the above described equivalent circuit , the output current of the photovoltaic article (I) can be expressed by the following equation
Individual parts of equations designated as I, II and III represent the generated current (I), the diode current (II) and leakage current (III) . This equation (1.8) reveals a significant

effect of seriál resistance Rs on the voltage-current characteristics of the photovoltaic cell . Series resistance decreases output current and thus the overall efficiency of the cell.
The semiconductor solar cell is actually a large LED - large PN junction, in which the incident radiation liberates some electrons of the crystal lattice , and thus free electrons and holes are created. These charge carriers are separated by the electric field, so the electrons accumulates on the top of the N-type semiconductor and the overflow of the holes is created at the bottom of the semiconductors P. When we connect (via the appliance) both sides of the article the current will flow through the circuit - electrons will move to fill the holes and thereby equalize the potential difference .
This is the actual direction of the current flow, while the agreed direction (direction marking in circuits) is reversed. The amount of electrons flowing through the circuit is the same as the number of electrons released in the PN junction due to irradiation. Electric current is therefore linearly proportional to the amount of the incident radiation. For the collection and removal of the charge the front part of the article is covered by a contact grid and the entire part is of a contact material.

FIG. 3.9: Representation of a photoelectric effect at the PN junction

Radiation, which causes the release of electrons in a semiconductor, cannot be random, the incident radiation photons must have the necessary energy. The size of the energy required depends on the used semiconductor, for silicon is needed the energy of 1.1 eV, which corresponds to radiation having a wavelength of 1100 nm.
Only photons with the shorter wavelength, ie.with more energy are thus utilized for the current generation. But their power is not fully utilized, because just one photon excites an electron and remaining energy causes the heating of the article. Because of these factors, efficiency greater than about 55% can not be achieved with silicon.
This is certainly a very good value, but because of further losses in the article, it is practically unattainable. Standard efficiency of solar cells commonly used ranges between 15 ÷ 18%. Manufacturers guarantee that power after 25 years will not drop below 80%.

FIG. 3.10: Si photocell sensitivity in comparison with the spectrum AM1, 5

To determine the efficiency of the solar panel γ this relationship applies at neglecting the contamination factor:
E AP×g = (1.9)
where P is the electrical power output (W), E radiant solar power W/m2, A panel area (m2)

3.2.3 Solar cells - types and production

Most widely used material for the production of photovoltaic cells is silicon (Si).

Due to the width of the band gap in silicon it is possible to reach very high efficiency generation of free carriers by incident sunlight. Simultaneously with silicon, as basic material for microelectronics, it was managed very well to handle all technological operations required to build the structure. The usable range of solar radiation silicon cells is shown in Figure 3.11.

FIG. 3.11: The usable spectrum of radiation for articles Si [4]

The starting material for the production of photovoltaic cells made of crystalline silicon are silicon wafers (typically P- type) of square shape with dimensions up to 200x200 mm and resistivity of cm units. The beginning of the production of the solar cells was associated only with mono-crystalline silicon. The need to reduce the input material prices resulted in the development of multicrystalline silicon in 1970s. This technology contributed to material savings and reducing investment costs, on the other hand, random orientation of crystalline grains does not enable texturing of the surface with alkaline etching and grain boundaries increase recombination losses . The development of technology has managed to significantly bring cell efficiency of multicrystalline silicon close to cell efficiency of monocrystalline silicon (efficiencies of various types of photovoltaic cells are shown in Table 3.3). [4] [15]

Tab. 3.3: Efficiencies of various types of photovoltaic cells [15]

Silicon articles - today, silicon is the most widely used material for solar articles, there are over 90 % commercially available cells made from silicon. 30% of silicon is contained in the Earth´s crust, and so its availability is not a problem . The problem is rather how to get him into a very clean image, which is necessary for the manufacture of articles, exerting a minimal amount of power and therefore the lowest price. Silicon waste from the production of semiconductor devices, which is used for these purpose, is not for the rapidly growing solar cell production enough .

· Monocrystalline silicon - expensive material to manufacture with high-efficiency of direct sunlight. The effectiveness of the produced cells is 14-17 %, 25 % was achieved at the laboratory.

· Polycrystalline silicon - often used in domestic installations. Efficiency in laboratory conditions reaches 20%, common cells to 16 %.

· Amorphous silicon - the efficiency is relatively low - about 5-7 %, but the article can use diffuse radiation better than the previous one. To improve efficiency, the materiál may be used in multiple layers, thereby efficiency up to 12 % is achieved.

Articles made from other materials, such as :

· Gallium arsenide - GaAs - with dopants (e.g., phosphorus, indium, germanium) is used for the production of solar cells with multiple PN transitions that can take advantage of a wider range of sunlight, maximum efficiency of 40.7% is achieved in the laboratory.

· Cadmium telluride - CdTe - the effectiveness of commercially produced modules is over 8 %, efficiency of 16% was achieved at the laboratory

· Copper indium diselenide - $CuInSe_2$ - laboratory efficiency is up to 18 %, their wider expansion is still prevented by their higher price.

One photovoltaic cell is made from one silicon wafer. The structure of the current article is shown schematically in Figure 3.13 . In order to achieve high durability, articles must be protected against environmental influences. An example of photovoltaic article from crystalline silicon is pictured in 3.12. Photovoltaic cells are inserted into the ethylene-vinyl acetate foil (EVA). The front part of the article consists of highly transparent, specially tempered glass, so that the elements are protected from moisture, wind, hail (hail to the diameter of 25 mm) and other weather conditions. At the same time, the glass should let through as much of solar radiation as possible. The back part is closed with multilayer plastic film with high strength or other glass layer. The modules are equipped with an aluminum frame for attaching to the supporting structure and the back wall is provided with a terminal block with cable pins and bypass diodes . A photovoltaic module is a compact unit with prescribed mechanical, optical and electrical properties.

1. aluminum frame, 2. Seal 3. Tempered glass, 4. EVA, 5. photovoltaic cell, 6. Cover foil (Tedlar)

FIG. 3.12 : Structure of Si photovoltaic module [17]

FIG. 3.13 : Structure of the photovoltaic cell [5]

3.2.4 Characteristics of the solar cell

The most commonly used solar cells characteristic is current-voltage characteristic.

The current for short (also short-circuit current) indicates the maximum current value, which is an article able to deliver at a given irradiation . It mostly ranges between 3-6 A, depending on the type of the article and its surface. Open circuit voltage indicates the maximum voltage of the solar cell without connected load. For monocrystalline cells it is about 0.6 V.

FIG. 3.14: VA characteristics and MPP of a solar cell

Working point is a characteristics point, in which the article is currently operating. Its location depends on the parameters of the load. Performance in the operating point is calculated as the product of voltage and the current operating point.

$P = U \times I$ [W , W , A] (1.10)

MPP (Maximum Power Point) is the operating point at which the performance of the solar cell is the largest. This point lies in the bend of volt-ampere characteristics, as the product of voltage and current, therefore power, is of maximum value, because the area of the rectangle created in the projection axis of the graph is the largest. At this point we try to operate the solar cell.

3.2.5 Factors affecting the performance of the solar cell

The intensity of the incident radiation has the largest impact on the solar cell performance because it causes the movement of electrons. The current of the article grows proportionally with irradiation. Tension grows only slightly.

Cell temperature has a contradictory effect on the voltage and current of the article. While at increasing temperature the current increases, the voltage decreases. But because the voltage drop is more significant than the increase in current, cell performance decreases with rising temperature at a rate of about 0.44 % · ° C -1. Therefore, especially in warmer areas, it is necessary to install more solar cells (modules) to achieve the same voltage and power.

The spectral composition of light also affects the cell performance because it uses different wavelengths with different efficiencies . In order to compare solar cells and modules between them effectively, performance measurement of cells is performed at the intensity of incident radiation of 1000 W · m -2 (equivalent to full sunlight) , the temperature of 25 ° C and the spectral composition of light corresponding to AM = 1.5. Thus measured power is defined as the peak performance marked as Wp.

FIG. 3.15 : Effect of irradiation and temperature of the solar cell on VA characteristics

3.2.6 Solar Panels

The solar cell is very thin and fragile and contacts on its surface would give way to corrosion without protection. These are the reasons why the approach to encapsulate multiple cells into solar panel is made. Figure 3.12

The structure of the panel has to protect individual cells from harmful environmental influences to achieve high durability. The front part of articles is covered with hardened glass that protects them from rain, wind and hail . As a material to which the articles are stored, ethylene-vinyl acetate film is used. The back part of articles is covered with hard plastic, resistant material called Tedlar is used . The finished panel is placed in an aluminum frame, which gives the construction rigidity and durability, e.g. against wind or snow, and allows easy installation. Each panel has contacts led either with conductors or waterproof terminal block .

Thin-filmed solar cells are often closed to reversibly transparent materials, and that for the case of fixing it to objects. Thin-filmed articles can also be flexible, in which case they are surrounded with the flexible film, and attached to the base by adhesive bonding.

3.2.7 Improving the efficiency of electricity production

When disregarding the efficiency of photovoltaic cells, the amount of energy that we produce depends also on the design of the panel and its location. But we must take into account the conditions of installation, so that we did not pay more than we got from the produced electricity.
Turning of solar panels towards the sun - this way can significantly increase the amount of produced energy, especially in the summer months. Turning may be uniaxial or biaxial.

FIG. 3.16 : Comparison of instantaneous systém performance with and without guidance and an example of panels with biaxial guidance

Uniaxial is easier and cheaper to produce and the panel is more resistant to wind gusts and is also easy to control. Turning axis may be horizontal or inclined in general.
Biaxial guidance is very effective, but considerably more complicated. Systems are rotated towards the Sun under computer control .
Guidance has a great effect in the case of direct radiation, the amount of incident diffuse radiation is not affected . Therefore, especially in the winter months, its contribution is small in our conditions. On the whole, guidance of solar panel sis interesting even in our conditions and its implementation depends on the price and type of solution .
The concentration of radiation - another way to increase the amount of produced electricity is to increase the irradiation of the PV module. This will be achieved by focusing radiation from a larger area by using lenses or reflective surfaces .
Lenses - they use the refraction of light to the focus where PV cell is located.
This technique has been known for a long time, but only now it is spoken about more often because of the existence of high-efficiency cells, such as GaAs . These cells are more expensive, but thanks to concentration very little material is needed, which reduces the final cost.
Fresnel lens are used for less material usage and space saving. They are made of plastic to save up the price. The disadvantage of this solution is the gradual loss of property - degradation of transparency.
· Reflective surfaces - help us increase the area from which we use radiation through the reflection of light, or extend the time of insolation of panels. Concentrators with planar reflectors and concentrators with parabolic mirrors can be used, but they are much more expensive, they require cooling elements and precise guidance. Reflective surfaces of the reflective concentrators have a limited lifetime because due to adverse weather they age rapidly and lose reflectivity .
Concentrators use only direct radiation and by their shielding reduce the possibility of the use of scattered radiation . Therefore, their use is cost-effective in areas with a higher proportion of direct insolation and fewer overcast days. Concentrators are often used in combination with guided panels towards the sun, it is necessary with lens and reflective parabolic concentrators for correcting focusing.

3.2.8 Solar PV grid-connected systems and their components

FIG. 3.17 : Block diagram of the solar system connected to the network

Besides the solar panels which are connected mainly in series to achieve higher voltages another component is an MPP tracker. Its task is to ensure that the photovoltaic field always worked in the maximum power point and we were able to make the most available energy . This tracker is already incorporated in modern inverters .

Following and very substantial part of the system is the inverter, its task is to create the AC voltage 230 V mostly with a frequency of 50 Hz out of varying magnitude of DC voltage. Solid state inverters specifically designed for operation with solar panels are used, they have huge range of input voltage, typically 200 to 400 V. These converters must also meet standards in the shape of the curve, the amount of the output voltage, distortion and others. The inverters can connect phases to the network themselves and in case of failure disconnect themselves from the network from the network.They are often produced in the design which allows the outdoor installation and are equipped with a status display and indicative measurements of produced energy and indications of energy parameters of a photovoltaic system.

They achieve a very high peak efficiency - up to 97 % ? , but only if they are burdened just under the maximum. Therefore, a higher number of lower power inverters are chosen, which are attached and disconnected based on the current performance of the PV field. Lifetime of the inverters is between 10 and 15 years .

A step-up transformer is behind the converter based on the voltage level to which the system is connected. Behind it there is only an electricity meter to significant measurement of delivered energy and a switch for connecting to the network.

3.3 Photovoltaic - thermal cells with solar radiation concentrators

The solar radiation incident on the surface of the photocells is direct or indirect . Indirect, so called diffuse component of radiation is formed by scattering of sunlight in the atmosphere or by its reflection from surrounding areas. The diffuse component of solar radiation is made up of a bundle of intersecting beams and dominates in case of cloudy weather when the direct component of sunlight is suppressed by cloudiness. A direct component of solar radiation, characterized as a bundle of parallel rays, predominates in cloudless weather when the diffuse component of radiation becomes insignificant. When the weather is cloudless the ratio of indirect to direct component of sunlight is about 1:10 [17]. Similar is thus the ratio of photovoltaic power systems under a cloudy sky to that of cloudless weather.

Instant electric power of photovoltaic - thermal system is primarily due to utility luminous flux Φe of solar radiation incident on the active area of the system, which is generally determined from the equation (1.3).

Φe = ∫ En (1.11)

where EeN is normal irradiance of surface element of dS photocell (W · m -2), ie the irradiance of dS pad projection in a plane vertical to the beam of sunlight. S is the total size of the active surface of photovoltaic - thermal system (m2).

FIG. 3.18 Direct and diffuse solar radiation component, a cut in composite flat solar radiation concentrator with horizontally and vertically mounted photovoltaic-thermal article

The active area of the photovoltaic-thermal system is usually composed of flat surfaces (flat photovoltaic cells with liquid cooler). In the case that just direct solar radiation (a beam of parallel rays) falls on the flat area, can be

Φep net radiant flux incident on the flat surface simply calculated as follows:

cosa 0 F = E × S × ep e (1.12)

wherein Ee is the plane perpendicular to the irradiation direction of the beam of direct sunlight (W · m-2) is S0

size of the active area of the photovoltaic cells with liquid cooler (m2), α is the angle between the normal

plane of the photocells and the direction of rays of sunlight (°).

Size irradiance Ee plane perpendicular to the direction of the beam of direct sunlight is

the place of the current position of the place with the sun and transmittance

atmosphere. Net radiant flux of direct solar radiation incident on a flat surface is

then only due to the size of the planar surface and its inclination to the direction of the direct rays

sunlight.

Required electric power can be an appropriate size of area

silicon photocells optimally oriented in space or the use of reflective surfaces ,

which can beam of parallel rays of direct sunlight to turn the volume

beam converging at a point, line or area . The reflective surfaces such

referred to as a concentrator of solar radiation . Use of such concentrators is

necessary to ensure sufficient cooling of photovoltaic panels using a liquid- medium

cooler installed on the underside of the photovoltaic panels . Such a system is then

referred to as a combined photovoltaic -thermal part because of its use occurs

combined production of electricity and heat. Concentrator solar radiation can be very difficult

used for directing the rays diffuse component of the solar radiation whose direction is dependent on

current weather conditions and rapidly changing over time .

The concentration of direct solar radiation takes place either a flat mirror or
mirror surfaces derived from conic sections (parabolic , elliptical hyperbolickénebo
Mirror) [19]. Reflective surface derived from conic usually direct the beam to
point or line. This is used in the article thermal heating fluids flowing
permeable tube whose axis is positioned precisely in line (or in pixels) where the
solar radiation directed reflective surfaces concentrator .
Concentrators for solar photovoltaics on the contrary, must concentrate volume
rays of sunlight to a point or a line , as this may cause irreversible damage
part of the planar silicon photocell , which would be too narrow focused beam
sunlight. It is advisable to use a system of plane mirrors or composite
planar reflective surfaces that do not focus rays of sunlight into too
small solid angle . Composition of several plane mirrors formed composite plane
concentrators . Examples of composite planar concentrators direct solar radiation
shown in Figure 3.18.
If we neglect the decrease in the intensity of solar radiation passing through the radiation fields
concentrator can net radiant flux incident on the Greek Official Gazette concentrator equipped with photocell
sunlight determined by the relation:
f r y cosa Cosby (1.13)
wherein Ee is the plane perpendicular to the irradiation direction of the beam of direct sunlight (W · m-2)
S0 is the size of the active area of the photocell (m2), α is the angle between the normal to the plane of the photovoltaic cells and
rays towards the direct solar radiation (°), n is the number of planar reflecting surfaces
concentrator (-), Si is the area of the projection of the i th reflecting surface in a plane perpendicular to the direction
direct beam solar radiation (m2), ρi is the reflectance of the i-th reflective surface (-), ψi is
21
coupling factor of the ith reflective surface with an active area of the photocell (-), βi is the angle between the direction
reflected rays from the i-th reflective surface with a plane normal to the photocell (°).
In the case of optimal design and installation of a concentrator can achieve greatness
coupling factor ψi → first
From equation (1.13) shows that the radiant flux Greek Official Gazette of the solar radiation incident on the active
photocell area may be used to add a concentrator (1.13) several times higher than
Φep radiant flux of direct solar radiation incident on the same optimally installed
photocell without concentrator determined from the expression (1.12) . To prevent damage
photocell , it is important that the performance of radiation that reaches the photocell must not exceed a certain

temperature stated by the manufacturer , or experimentally determined for a given photocell.
Using the concentrator to direct sunlight can increase the performance of radiation incident the active area of the photovoltaic thermal system under conditions prevailing direct from the sun (no clouds) and can ensure a sufficient thermal capacity thermal parts of the system (which serves as a heat sink for photovoltaics) . Barring exceeding the allowable limits radiant flux incident on a photocell , are possible corresponding increase electrical output of the photovoltaic system. For correct function of the concentrator must use shooting concentrator system and photocell [18] evaluating the path of the sun changes after sky.
Using concentrator direct sunlight when direct sunlight suppressing the influence of the atmosphere and the prevailing diffuse radiation , there is a partial reduction performance of the solar radiation reaching the photocell (due to shading of the upper half- reflective surfaces concentrator , eventually . improper orientation of the photocell in concentrator - Figure 3.12 on the right) and thereby reduce the electric power and shutdown thermal part of the system at this time.

3.4 Trends in photovoltaic cells and modules

The current development of technology suggests that crystalline silicon will remain the most important material for the production of photovoltaic cells at least the next five years , and it Given the continuing decrease in prices of input material, reducing energy performance and further improvement techniques to ensure high reliability and life modules with cells made of crystalline silicon. It will also continue the development of thin-film technology , both based on amorphous silicon (or Si -Ge) are based CdTe or CIS . The share of thin-film modules in total production can be achieved in the next five years to 25%.
At the same time an intensive research and development of other technologies of photovoltaic cells and modules such as

· Articles with multiple bands
· Cells using quantum phenomena in quantum dots or quantum wells
· Organic Articles
· Grätzlovy cells (cells based on nanoparticle TiO_2).

All these technologies are very promising in terms of future options realization of inexpensive photovoltaic cells and modules , but are currently still

still in the stage of research and development. You can not , therefore, expect the next five years
significant expansion of these technologies. Over the long term , we can fotvoltaické articles divided as follows :
[6]

· Articles of the first generation
of PV cells are most common from monocrystalline silicon panels , which together form a PN junction . PV cells are sold from seventies until today , where it forms the bulk of the market and about 90%. They are characterized by a very good life while maintaining efficiency in the mass production ranges from 14% to 17 %. The production special , for laboratory purposes , the efficiency as high as 25 %.
The disadvantage is that the production has to be used a large number of highly pure silicon .

Articles second generation
Here there is a significant reduction in the amount of pure silicon. At the same time starting to use elements other than silicon. Most often they are replacing polycrystalline and amorphous silicon with a much thinner layer compared previous generation and up to 1000 times . Reducing the amount of silicon adversely affects the efficiency of the panel (about 10 %) , on the other hand, we thin profile saves weight and improved mechanical properties , in particular Flexibility . Today, you can also purchase the commercial sector futuristic study backpacks and other equipment with integrated solar panels . interesting solution multifunctionality can be found on the FV meeting insulating foils requirements for flat roofs with simultaneous production of electricity.

· Articles Third Generation
an area which is still ongoing intensive research work. Efforts to maximum use of energy of incident photons of sunlight , mostly in the form of multiple transitions of thin layers. watch
You can also attempt to use other methods of separation of charges than PN transitions.
Photoelectrochemical (photovoltaic) cells or the use of nanostructures in form of carbon rods and tubes , or quantum dots deposited on appropriate base. Specifically , there is then possible to affect the electrical and optical properties for efficient use.

Articles fourth generation
the final evolutionary step fully understand the multi-layered profiles using a wide solar spectrum. Layering profiles is based on principle tuning layers on different wavelengths. Wavelength of radiation changes frequently. When solar irradiation on the layer that had not use, then there is a release of radiation to the layer, the wavelength corresponds to the appropriate use.

3.4.1 Articles of crystalline silicon

When comparing the various technologies are usually based on high energy
intensity of production of crystalline silicon required purity.
One of the main trends in the development of photovoltaic cells is to reduce the thickness plates at 200 to 150 micron, which leads along with increasing cell efficiency significantly improving performance produced the same amount of silicon. Besides achieved
reduce power consumption during the preparation of the starting material . From 2000 to 2007,
reducing energy consumption required for producing 1 kg of polycrystalline silicon with sufficient
purity for solar cells (SOG) by 46 % and there was a significant decline in the price of silicon (from 500
USD / kg in 2008 to the current 55 USD / kg). The gradual improvement of production technology (along with the effect of mass production) leads to significant reduction of production rates
modules , which currently has decreased to a level of around 1.5 € / Wp. At the same time the development takes place in
improvements in the quality of technological processes in order to increase the effectiveness of current
12-17 % to 18-22 %. Compare prices of different types of modules at the beginning of 2010
is shown in Figure 3.19.

FIG. 3.19 : Comparison of prices of various types of solar cells [5]

On the other hand, the price decrease SOG silicon leads to the fact that the price of modules (expressed
price for 1 Wp) produced using different technologies varies relatively little . [16] Low
price of crystalline silicon modules can slow the growth of production of thin-film modules.
Currently, intensive research and development of other photovoltaic technologies
cells and modules , such as articles with multiple belts cells using
quantum phenomena in quantum dots or quantum wells , organic and articles
Grätzlovy cells (cells based on nanoparticle TiO_2). All of these technologies are highly
promising in terms of future options for inexpensive photovoltaic cells and
modules , but are currently still in the research stage or development. their
significant expansion can therefore expect the next few years .

3.4.2 Thin Film Modules

In the field of thin-film modules are being developed primarily towards the cheapening

technology (eg increasing the deposition rate of each layer), increased efficiency and stability of cells and modules of the current 6-10 % to 10-15 %. This places great demands the technology solutions that represent the major part of the cost items. In
thin-film technology is a great potential to reduce the price of the modules relative to the lower
However, the effectiveness of the final price of photovoltaic systems practically the same as compared with FV
Systems implemented crystalline silicon . However, there are currently built
relatively large proportion of production capacity and production of thin-film cells is growing.
In thin-film technology are not realized individual PV cells, but the entire module
sequence of technological operations . The carrier substrate (usually glass) is initially deposited
layer TCO (transparent conductive oxide) and laser are separated by areas of each cell shaped strips (removal TCO). The following plasma deposition of thin-film cell and Article laser removal of structures in the strip lying close to the boundary defined by the first laser cut. Then, the deposited metal contact (usually sputtering) . The third cut with a laser to remove metal contact strip to form a module structure series connected cells (Figure 3.20) . On the back of the module is laminated cover layer (glass or polymer) terminals and drained into the terminal . The efficiency of thin-film modules is in the range of 6-10 %.
Thin film cells and modules may be implemented also on flexible sheets, which simplifies some roof applications . Problems with the stability of the deposited layers and high
price necessary technological equipment have led to an increase in the proportion of thin-film PV modules in total production occurred after 2006 , which reflected the shortage of silicon caused a sharp increase in photovoltaic applications. However, Currently, the stable deposition of thin layers of technologically mastered desktop module up to 5 m2 and a gradual increase in their production.

FIG. 3.20: Structure of thin-film photovoltaic module [15]

3.4.3 Distribution of photovoltaic systems by involvement

Photovoltaic systems can be in terms of application divided into three basic types:
· Autonomous Systems,
· Hybrid systems with accumulation
· Systems directly connected to the network without accumulation.

3.4.3.1 Standalone and Hybrid Systems

Autonomous systems (or systems Grid-off) are mainly used in places where is not available to the public electricity network. These systems consist of photovoltaic

modules, batteries and protection circuit that protects the rechargeable battery be against excessive discharging or overcharging. Larger systems may include a voltage converter.
Block diagram of an autonomous photovoltaic system is shown in Figure 3.21.
Autonomous systems use special rechargeable battery designed for
slow charging and discharging. The optimal charging and discharging of the batteries is ensured
Regulator Rectifier. The island is possible to connect a DC powered appliances
current (system voltage is usually 12 or 24), or a common network appliances 230
V / ~ 50 Hz voltage supplied via the inverter. Such systems have application, for example as a source of
electricity for cottages and other buildings, power traffic signals, telecommunications
equipment or monitoring devices in the field, with garden lights and neon signs.

FIG. 3.21: Block diagram of the Grid-off [10]

The hybrid photovoltaic system is essentially a combination of wired network stations (Gridon)
and insular system (Grid-off). In contrast to systems Grid-on (viz.následující chapter) have
hybrid photovoltaic systems benefit the maximum use of the energy produced at the site
production, whether in the form of electricity or for heating, water heating, air conditioning, irrigation and operation of the pool or other predetermined appliances without unnecessarily
delivered too much energy into the grid.
Another advantage of a hybrid photovoltaic system is already integrated functions
for the use of surplus energy in peak power when intelligent hybrid drive is already
today can divert excess energy in real time or with a delay in the controlled
You predetermined, energy-intensive appliances. Example of hybrid fotovoltaickho
system is shown in Figure 3.22

FIG. 3.22 : Hybrid photovoltaic system [11]

3.4.3.2 Systems connected to the electricity grid (Grid - on)

The advantage of Grid systems -on is the fact that all electric energy produced in the
Unlike systems Grid -off processes . These systems are usually of a plurality of skádají
photovoltaic modules , voltage converter (inverter) , a device for measuring and controlling a network
protection. Connecting PV systems to the grid can be done in
two basic versions , as shown in Figure 3.23 and 3.24 .

Figure 3.23 represents a system involvement in so-called green bonus . The main house cabinets (HDS) is equipped with four-quadrant meter (4Q) and it is connected to the house distribution and power plant using another meter. This connection is used in cases where it is
the bulk of the electricity produced captive use an object with an installed photovoltaic system .
Figure 3.24 represents a system involvement in the so-called feed-in tariff. photovoltaic Power in this case is connected between the existing meter and the main house SKRN (HDS) using a four-quadrant electrometer. The connection system is used in
, where is all the electricity generated into the electricity supplied by the manufacturer systems.
The houses are usually installed systems with capacities ranging from 1 to 10 kWp. for investors are much more interesting systems installed on the roofs of larger housing or residential complexes , or installations in the open (20kWp to drive
MWp) .

FIG. 3.23: Connecting the system for their own consumption [15]

FIG. 3.24: Connecting the supply system to the network [15]

Measurement delivered and consumed electrical energy is different for systems up to 20 kWp and
above 20 kWp. For systems up to 20 kW, for determining the supply and consumption using direct
quadrant electrometer. For systems over 20 kWp is metering and supplies provided follows:

· Indirect measurement of supply 4Q meter on the LV side of the transformer (up to 600 kVA)
· Indirect measurement of supply 4Q meter on the MV side of the transformer,
· Separate metering.

3.5 Power plant design, design of individual components

In the design of photovoltaic systems is the need to pay attention to safety and trouble-free operation, minimal maintenance requirements, maximizing energy gain and minimize energy losses. The basic criterion for the assessment of control traffic Photovoltaic power is its operating performance (PR), we can define the following equation:
PR- × ×=0(%) (1.14)
wherein:

E. .... total produced electricity (Wh)
GE .... total incident solar radiation (Wh.m-2)
A. .... total area of PV panels (m2)
Effm .... efficiency of PV modules by the manufacturer (%)
UO .... the total amount of solar energy that can not be inverted to
energy (Wh.m-2)
Each solar system in an outdoor environment should be equipped
protection against voltage surges and lightning , and that both the DC and the AC side . Z
to minimize line losses may not always be advantageous to minimize sections
DC line . Especially for systems with high installed capacity , we can
experience with large-scale distribution on the DC side with a voltage up to 1000 V.
3.5.1 Preparation and construction of photovoltaic power plants
Penetration construction of photovoltaic power plants can be divided into the following steps :
· Professional inspect equipment on site
of finding usable area , verify that the site is not shielded , control options
fastening and anchoring structures, roof load , design options
cable routing and connection of the plant site
· Preliminary sketch of the technical implementation on the basis of inspection and construction drawings and
determination of installed capacity by the technical possibilities and financial concepts
investor
Application to connect to a local electricity distributor
· Request the consent of the property owner installs if FVE to a building or any
neighboring land owners and municipalities for the installation of photovoltaic power plants
at the free surface
· Copy of connectivity study
· Preparation of project documentation and building permit

3.5.2 Technical solutions FVE

In general it can be said that almost 80% of the total cost of the photovoltaic system
consists of photovoltaic panels, inverters and supporting constructions. It is therefore always important to find a
a technical solution that will be for the site and the type of installation to provide maximum utility for the investor. Individual components of the photovoltaic power plant are seen in Figure 3.25. Each installation can be divided according to three basic indicators:

· Installed power
on systems up to 100 kWp
? Inventors low power (1.5 - 8 kW)

the systems above 100 kWp
? Central inverters with an output of 40 to 1000 kW
· Support structure
a fixed (static) systems
the adaptive systems
? uniaxial
? biaxial
placement
the roofs of buildings - solid systems
the integration of building envelope
the installation in open areas

FIG. 3.25 : The components of a photovoltaic system [15]

The starting point for the design of photovoltaic power is the definition of its use. when determine the optimal size of the installed capacity of the plant really care what primary requirements of the client - if the main requirement is to "get on the roof as much as possible " , or
For example, "optimize power and make the most produced for consumption by the building ."
In the first case, the maximum size of the plant depends on the size of the roof , and since 2011 also
actual legislative restrictions , which allows the installation of power plants up to 30 kWp.
For optimizing the power consumption efficiency to the point of production (and hence the the best return on investment) is necessary to reckon with the fact that the larger the production (and thus
size) power consumption in proportion to the object , the smaller the percentage of electricity produced
plant will be used in place of (excess will be fed into the distribution network) . In the real situation also depends on the consumption of the building - the optimum condition when the main power consumption in the building
is required during the day (eg, schools , factories , office buildings , etc.). In
the case of houses, where consumption is directed more to the early morning and late afternoon and evening hours , the situation is balanced production and consumption a little complicated. This balance improving weekends , heating (eg heat pumps, heaters),
who work during the day and the next 'day' consumers (eg air conditioning , pool heating , etc. .) .
It is also possible to redirect part of consumption (offset starting dishwashers, washing machines, etc.) and so
The resulting ratio improved.

3.5.3 Selection and Configuration design of photovoltaic panels

From the technical point of view there is no single universal solution ideal design. optimum proposal photovoltaic power always comes from the experience of individual designers . usually
are used in photovoltaic panels with output of 160 to 240 Wp. In ideal conditions have Panels usually the output DC voltage of 40 V and a current of 5 A.

3.5.3.1 Design and layout orientation panels

When designing a photovoltaic power plant is important the correct orientation of photovoltaic panels.
For maximum utilization of solar energy panels is ideal orientation towards the south.
Diversion panels a few degrees to the southwest or southeast ONLY
a minimal effect on the total energy produced . Generally, states that a change in orientation 20 ° from the southern direction, the power output is reduced to 5 %. In the case of panel orientation direction
east and west of the decline
Build significant, up to 25 %. [11]
Ideal inclination permanently installed panels in our latitudes is about 33 ° .
It is a compromise between yield power when the sun low on the horizon (winter) and
high in the sky (summer season) . Again, the difference in the installation slightly different from the optimal
position has little negative impact on the overall energy yield . When installed in
between 10 ° - 60 ° is performance drop to 10 %.
Higher performance will decline when fitting the panels vertically (eg facades) , and about 25-30%.
These parameters apply to panels made from crystalline silicon. Amorphous panels are generally lower efficiency, on the other hand are less sensitive to the need to direct sunlight and, for example , when installed on a vertical wall in the same area can deliver similar performance as
polycrystalline or monocrystalline panels

FIG. 3.26 : Design space between panels [15], [2]

The information also shows that when optimizing photovoltaic system for winter
conditions (e.g., off - grid systems used to store energy) is the optimum location
panels in an almost vertical position (= > perpendicular to the rays of the sun located low on the
horizon) .
During the construction of photovoltaic power plants in the open or on a flat roof is

very important to determine the optimal spacing between rows of panels. These spacings usually determine the worst case scenario , which is when the sun is lowest over horizon. In our area direct sunlight in the winter landscape under a = angle of approximately 17 ° . In Figure 3.26 you can see the layout of panels needed just at the specified conditions.
Another important issue in the design of photovoltaic power plants is the elimination of any partial shading caused by trees , surrounding buildings , power poles etc. Even partial shading panels can result in significant reduction in energy profits particularly in the event that this would be shading periodic with which it was not in A design FVE calculated .

3.5.3.2 Supporting and design elements

A significant part of FVE is undoubtedly the supporting structure for the panels . structural systems can be divided according to the type of installation :
· The construction of the pitched roof
o Suitable for small installations on houses with gabled roofs with a slope approximately 35 ° and oriented to the south or southwest. The key element here is aluminum profile laced with special hooks to the roof structure (Figure 3.27) . The profiles are mounted PV panels . This design is perhaps the the most widely used especially for its simplicity , ease of installation and low cost.
· Design for flat roofs
Such a structure is usually formed galvanized steel profiles triangular shape, which are mutually " bracing " and the spliced aluminum profile for mounting solar panels. The structure of the roof mounted either fixed chemical anchors or concrete loaded blocks or tiles (Figure 3.27) .
· Construction of open area
the same solution as for flat roofs is used in large power plants constructed in open areas , with the difference that the construction is connects firmly to the ground and either studs , galvanized profiles zatlačenými in the ground or concrete foundations (Figure 3.28) .
· Positioning Systems
o Another possible , and what to yield, the best way to mount PV panels are positioned so called trackers systems (Figure 3.29) . Tracker automatically rotates and flips the panels to the sun in his tracks and astronomical thus allowing maximum extraction of FVE . Experience talks about 30-35 % increase in yield compared to conventional fixed installations. The disadvantage , however, remain high initial investment costs , private consumption and system maintenance required .

FIG. 3.27: Possible variants of mounting panels on the roof of the saddle [15], [2]

FIG. 3.28: Mounting the panels on the roof and open space [15], [2]

FIG. 3.29 : Adjustable systems for storage panels [15]

3.5.4 inverters

Photovoltaic panels produce direct current only , which is necessary to change the current alternating , in order to connect power to the electrical grid. device allowing
This transformation is called the inverter or the inverter . Used inverters are also capable of provide information about the actual production of electricity.
The inverter must deliver maximum performance with minimum losses . This can be done removing the transformer with a consequent reduction of heat losses and using equipment tracking the maximum power point (MPP) , which changes the input resistance ensures optimum operation of the inverter . Přifázování inverter (connect power from the panels to the grid) is fully
automated. The inverter has a life outside influence other design solutions - cooling natural air circulation without using a fan. For a particular application are made Inventors island and network .
The island generates its own frequency , which corresponds to the frequency on the grid (f = 50 Hz). Thus it is possible to use this network home electrical appliances AC .
Network inverter synchronizes its frequency and voltage with current data distribution networks .
In terms of involvement in the FVE inverters are divided into:
· Modular inverters (inverter is connected only to one PV module)
· String or the string (each inverter is connected to several PV panels interconnected in series , or even parallel)
· Central inverters (connected to hundreds or thousands of solar panels).
Examples of involvement of the various types of inverters are given in Figure 3.30 . The modular
inverter (A) to meet very rarely , only for small systems . Medium-sized plants use string inverters (B) . In the case of large power plants is used as a concept large central inverters (C) as well as a large amount of string inverters .

FIG. 3.30: Examples of wiring inverters [2], [14]

3.5.4.1 Basic parameters of inverters

When selecting a suitable inverter is needed to properly define its parameters.
The basic parameters of inverters include:
· Nominal Power AC and DC sides
· Maximum input voltage,
· Voltage Range MPP tracker
· Efficiency inverter
· Internal configuration
the number of independent MPP trackers
the number of power stages
the possibility of communication, etc.
· Maximum input current
· IP protection
Examples of internal wiring of the inverter are shown in Figure 3.31 and 3.32. The advantage transforátorem inverters with galvanic separation and higher security and the ability to use photovoltaic panels based on thin-film technology. A disadvantage, however, increased loss of a large mass. Compared to achieve operational efficiency inverters with transformer EFFICIENCY about 1-2% lower than transformerless inverters.

FIG. 3.31: Internal wiring of an inverter with transformer [2], [15]

FIG. 3.32: Internal wiring of the inverter without transformer [2], [15]

6.3 Forecasts of the current state of "the end of the solar boom in the Czech Republic?"

Investors who in 2010 built a small solar power plants are currently
s Regulatory Authority (question the purchase price), and problems with semi company ČEZ, as this
company as a monopoly purchaser is joined only in 2011, with the purchase price of 5.50 CZK / kWh,
against the original price of 12.40 CZK / kWh. About fifteen years of law guaranteed return on investment
these companies can only dream of.
Another problem that the state is prepared, temporary withholding tax of 26%. The problem with lower
purchase price covers around fifty investors in the areas of agriculture, engineering and wood production. Most of these investors have built their own solar power mostly to

performance of one megawatt. Table Table 3.4 provides basic information about the amounts
purchase prices since 2006.
How much solar power received in the so-called "green bonus" in CZK / MWh
Births 2006-2007 14310
2008 13952
2009 to 13014 30kW / 30kW from 12912
2010 12055/11953
2011 to 30kW 100kW 6853/do 5190/nad 100kW4773
2012 to 5334 30kW
5 kW to 30 June 2013 in 2460/1880 to 30kW
from 1 July 2013 to 5kW 2040/1480 to 30kW
Recently, there is a stagnation in growth of the solar power plants at present
value of approximately 2,100 MWe, while the number of solar power plants reached number 21975th
The opacity of the Czech state in the solar business case testifies giant solar
plant, which built opaque company Amun.Re who joined before the end of the year
2010 for more advantageous conditions regarding the purchase prices and "green bonus"
while building inspections were up in 2011. On these few examples it is seen that even so ecologically interesting technology may become hostage to a hard business, with the participation of
politicians.

Photovoltaics in 2013

Since January 2013 there has been a significant drop in prices for electricity produced
of photovoltaic power plants. If we compare it with 2009, for example, is almost a tenth of the
prices.
· For a photovoltaic power plant to 5kW with access to green bonuns is
priced at 2.86 CZK / kWh. This price, however, will be reduced from July 2013 to
2.44 CZK / kWh.
· For a photovoltaic power plant over 5kW connected to the green bonuns
priced at 2.28 CZK / kWh. This price, however, will be reduced from July 2013 to
1.88 CZK / kWh.
But despite such a low price is to install solar power is still recoverable. This is due to still
falling price components for photovoltaic power plants.
Model pricing Photovoltaic power plant 5kWp to join in
distribution in the object (the so-called green bonus)
Photovoltaic power price
20pcs panels power 250W, 3 phase inverter Kostal pico 5.5 - Installation of the 1st mid-

2013

· Discharge permit the plant to CEZ (CEZ solves about 2 months)
· Development of design documentation, referral to agree on CEZ (CEZ solves about 1 month)
· Delivery Technology
· Installation on the roof, connecting the inverter located in the utility room
· Connection to the electrical distribution
· Preparation of inspection, preparation of documents for the license, the license application, (ERO addresses about 1 month)
· Transmission license to CEZ application for the first parallel connection of the plant
· Total cost excluding VAT 220 000, - CZK including installation

the total annual profit incl. savings of about 22 500, - CZK (at purchase price of CZK 2.28 / kWp and private consumption about 60%)

The return on investment of about 8.6 years

3.7 Issues and challenges

1) . Light and infrared radiation the sun is in the wavelength range of 0.2 to 0.3 millimeters . Calculate the frequency of this radiation.

2) . Describe which parts of the heart consists of the Sun, which brings its energy from which components of the solar radiation consists of what part of the radiation is applied to photovoltaic systems.

3) . Explain concept of the solar constant , contamination factor as defined optimum angle for maximum sunlight throughout the year.

4). Explain the principle of operation of a photovoltaic cell , under what conditions the photovoltaic energy conversion.

5). Describe the construction of photovoltaic cells , solar cells types and their properties

6). Distribution of PV systems , basic wiring autonomous and hybrid systems.

7). Explain the problems of design of PV power plants , define the term operating performance of PR , the block diagram , explain the components of photovoltaic systems.

8). What function is performed by the inverter circuit , what types of inverters are used , give examples involvement .

9). Describe the economic balance of the proposal elektrovoltaických systems , explain the concept of " Green bonus" .

10). Develop an essay about "The Future Ozee in the Czech Republic , as I imagine

its contribution to environmental protection in their neighborhood. " (My future housing).
11). Calculate the efficiency of the solar panel area A = 1m2, which supplies electrical power P = 140W at a glittering solar power E = 1 000W/m2 .
(Hint: refer to chapter 3.2.2)

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