TALLINNA TEHNIKAÜLIKOOL
TALLINN UNIVERSITY OF TECHNOLOGY

Department of Materials and Environmental Technology

«ONLINE PHOTOVOLTAIC PERFORMANCE CALCULATOR BASED ON THE OLMO MODEL»

«VEEBIPÕHINE PÄIKESEPANEELIDE TOOTLUSE ARVUTUSPROGRAMM OLMO MUDELI BAASIL»

MASTER THESIS

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(*On the reverse side of title page*)

AUTHOR'S DECLARATION

Hereby I declare, that I have written this thesis independently.

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Department of Materials and Environmental Technology

THESIS TASK

Student: Artur Dzhafarov, 165556KAYM

Study programme: Materials and Proccesses of Suitstainble Energy

Main specialization: Processes for sustainable energetics

Supervisor(s): Andri Jagomagi, research scientist, (620 3374)

Thesis topic:

(in English) «Online photovoltaic performance calculator based on the Olmo model»

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Thesis main objectives:

1. The algorithm calculation analysis on the basis of Olmo model
2. To create a web application based on the algorithm of calculation

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Collection of information in sources, finding of formulas and description for calculations	22.10.18
2.	Analysis of calculations and their performance in Excel	25.11.18
3.	Creation of prototype and design of the website	14.01.18
4.	Page-proofs and displaying in the browser	17.02.18
5.	Calculations and initial data transferring from Excel to SQL, connecting the map and working with queries	22.04.18
6.	Complete website and transfer to hosting, the error checking	10.05.18

Language: English **Deadline for submission of thesis:** “......”....................201….a

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PREFACE

One of the objectives of the thesis is to show a review of the existing situation in the field of renewable energy, namely, to concentrate on development of the additional concepts for calculating solar panels. Since a human being currently has lived in the age of information, it is necessary to use available resources to solve new problems.

Therefore, in order to accelerate the ability to read the necessary values, an online calculator model was developed to calculate the parameters of the module. Of course, it cannot be said that this idea represents something revolutionary new, but when it is viewed from the point of view of web design, it makes it clear that this website gives a simple calculation model, in which even a non-trained user can understand without additional explanations.

In this thesis, the main provisions for the calculation of solar energy using web resources are described. The description of solar energy as a whole, calculation of radiation, beginning with the study of the position of the angles of the azimuth and the angles of the inclined surface, as well as the use of the Olmo model as the main calculations were given. And by combining this model with web design technologies and programming, we are able to calculate the necessary parameters of the solar panel in the shortest possible time using the online calculator site.

Web design, calculator, solar panel, solar radiation, Olmo model

Master's thesis

CONTESTS

INTRODUCTION

The world has changed and it is still changing. With the colossal greed of consuming fossil energy resources, the world community only asks one question: What next? It is already necessary to think about how to preserve the habitual way of people’s life while preserving the environment, because the extraction of fossil energy resources does not remain unchangeable, since the depletion of oil, coal and gas deposits a global energy catastrophe is possible.

Thus, there remains only one solution and it is alternative renewable energy, in particular, energy of the Sun, wind, water and other sources. It is possible to provide all people for coming years with the proper use of land resources.

In fact, renewable energy and saving energy are the only way to the future and to the survival of world’s population. The ability to use the sources and technologies properly, which is possible to obtain energy from, not to use non-renewable natural resources, to reduce dependence on natural raw materials is our number one priority.

Nowadays the present economy directly depends on resources that have been accumulated for millions of years: oil, gas, coal and others. Much of human life depends on the provision and use of transport and household activities which require the burning of these fuels. The main problem with these resources is that they are non-renewable ones. In the nearest future, mankind will pump out all the oil supply, burn all the gas and dig out all coal supply, which means that there will come a turning point when they have to be replaced by alternative sources. [V. Germanovich, 2014]

It is also important to take into account the negative impact of fuel consumption; in particular, the increase in the amount of greenhouse gases in the atmosphere increases the average temperature of the whole Planet, including air pollution, which happen large cities.

It is important to think about the future today! Even if this future will be not with us! World leaders haven’t recognized the limitations of fossil resources for a long period of time and gradually, but rapidly they have started to introduce and invest money into the development and the gradual transition programs into renewable energy sources.

Of course, there are great amount of worthy replacements to fossil sources, like solar panels, wind installations, geothermal stations, hydroelectric stations, etc. And many countries successfully introduce their projects, but they are not also deprived of their shortcomings. The main problem is in the geographical distribution of resources, for example, wind installations should be located where winds often blow, and solar stations must have a lot of Sunny days, hydropower plants must be constructed on large rivers and lakes. [V. Germanovich, 2014]

Another problem is the instability of renewable energy sources. So wind installations directly depend on wind, on its speed and intensity; solar power plants operate at low efficiency in cloudy weather, and they do not generally work at night.

The energy of wind and Sun does not take into account the needs of people, while the energy of a thermal or nuclear power plant can be easily regulated. To solve this problem, it is possible to construct large energy reserves instead of reserve with low energy production. On the other hand, this approach will cause a rise in the expenses of the entire system in a whole. The development of renewable energy sources is slow for this and other reasons, and thus the use of fossil fuels is easier and cheaper [V. Germanovich, 2014].

Renewable energy in the world does not provide much benefit at the moment, but in individual houses they can be quite beneficial by installing few solar panels and a small windmill.

According to the forecasts of companies engaged into the development of technologies for renewable energy sources, within 5-10 years these technologies and the opportunity will become highly competitive and get mass distribution, the production costs will be reduced and hence, the final price will also be reduced.

During the period of 2016, renewable energy sources have accounted at about 23% of world production, where 27% is for the volume of electricity produced, and approximately 59% of the newly created capacity. Such rapid dynamics occurs in places where geopolitical tensions are decreasing, related to their development. It is possible that it can be argued that the transition to the use of alternative energy sources will lead to a reduction, if it is possible, of conflicts and claims related to resource consumption [Alkhasov A.B.].

It is also very important to conclude that, with regard to geopolitics, the transition to renewable energy sources will put an end to fossil sources, thus shifting relations on an interstate scale. As a result, the massive development of renewable energy sources in the global energy balance can cause the generation of new links. [Alkhasov A.B.]

Thus, it can be remarked that a new era is coming for mankind .It is the age of renewable energy technologies, while the era of oil has already ended, which is acknowledged by many scientists and of course, experts in the companies which earn on oil and gas.

1. SOLAR ENERGY

1.1 Solar energy: general concept

Solar energy is inherently an industry that develops methods and means of using solar radiation and solar radiation of producing electrical, thermal and other types of energy for the use in household s and houses. The solar energy that enters the Earth is the most significant source of energy that a human being has. The flux of solar radiation energy can be compared with conventional fuel in the equivalent of 1.2×10^{14}. (Alkhasov, 2012)

Today the using of solar energy is common for providing heat carriers, in particular, for hot water supply, heating water in swimming pools and heating in buildings. Solar energy is also used to produce electricity in power plants that operate either in a thermodynamic cycle or with direct conversion of solar energy into electricity.

The Sun is a hot gas and it contains 82% of hydrogen, 17% of helium, and about 1% of other elements. Inside the Sun itself, there is a zone of high pressure, in which the temperature reaches 15-20 million degrees. The distance from the Sun is approximately 150 million km. The flux of solar radiation that reaches the Earth, according to different data, is equal to (7,5-10)*10^{7} kWh/year or (0,85-1.2)* 10^{14}kW, which in sum is much higher than other sources of renewable energy. (Alkhasov, 2012)

Solar radiation on the Earth's surface depends on many factors: the latitude and longitude of the terrain, its geographic and climatic features, the state of the atmosphere, the height of the Sun above the horizon, etc. Sunlight daily produces a huge amount of energy. To describe the scale, the energy is enough to provide all the needs of all people in the world within one hour. Despite all above solar energy is a new technology in comparison with conventional energy sources, such as gas, oil and coal. What is the possible reason for this situation?

In fact, the main difficulty is in obtaining energy using efficient and economical devices. That is necessary to use solar radiation (insolation), which consists of electromagnetic waves and transform them into useful heat and electricity.

For these processes, a material capable in absorbing photon energy is needed, by placing the electron at a high energy level. The heat that was produced by the electron gets back into the region with low energy level to cause the surrounding atoms to vibrate, by exchanging energy [Hache, 2017].

The greater the vibration, the more it corresponds to the high temperature, so the energy after the exchange provides useful heat. Electricity production requires an electron not to fall to a lower energy level, instead of its opposite partner (a hole) moves to different electrodes, and their potential difference would feed (activate) the device. Thus the effectiveness of these electronic processes dictates the success of using solar energy [Hache, 2017].

It is extremely important to ask yourself a concrete question: how much, in general, do we need to create devices and collect the energy produced by the Sun? It all depends on what angle is to be considered in the issue. The point is that if this question is asked to people who monitor the situation in the market of energy resources, such as coal, oil or natural gas, it is quite possible that they will be able to convince that these energy sources will last long. In particular, as coal, which is the longest and can last for another 1000 years to meet all the current requirements of society?

Another question is the following: there is a constant population growth. According to the UN the world population will increase until 2100. It will possibly be about 9 billion people on the Planet. So will the future population cause a load on the consumption of existing energy supplies? Presumably, in the nearest future the number will increase by 30 % on the Planet and if we start from the fact that energy consumption for every person remains unchanged, there still are a lot of resources. [Hache, 2017]

But the main problem is not in the population, but in those emissions that are generated with the combustion of fossil fuels, and solar energy is one of those technologies that can save or at least reduce the influence and emission of greenhouse gases.

It is important to note that solar PV electricity has a distinct advantage comparing to others, because it is produced directly by the current (DC). At the same time, many people use digital devices (cameras, telephones, computers ...), which are ultimately powered by low-voltage (LVDC) electric energy (DC), and in modern houses and buildings they convert AC to DC power using a transformer and an inverter. Thus PV of the generated electricity can be used for digital power devices at a reduced price.

The question remains, what research is being done on the development of solar energy? In comparison with the research conducted over the past hundred years it has been on the optimization of fossil energy sources.

Solar thermal and PV power plants require less time for their installation and development, which indicates the direct benefit of their use. An excellent advantage of solar power plants is that they do not require water for cooling the system. So water, itself, is available resource which does not cost-expensively to spend. But the disadvantage of such systems is the dependence on weather conditions and time of day.

The production of hydrogen from photovoltaic systems can be used as a method of chemical energy storage for the future use. And molten salts can be used to store energy for a cycle of thermal energy. The solar energy is rapidly developing, taking its place in the fuel and energy complex of several countries. [Hache, 2017]

The main and most important source of energy is the Sun. Indeed, it is surprising that materials are developed that they can absorb this energy and produce electricity. Nowadays the priority task is in the competent use of what has been developed for the rational consumption of electricity and the use of heat economically and environmentally.

To provide for all people living on the Planet, it is necessary to spread the technologies of alternative sources, starting, first of all, with the poorest areas, because the need to have at least one source is better than none at all.

Based on the nature of the area, for political and economic reasons, energy should be distributed evenly to everyone, not from a central source. It is also necessary to take into account that the development focuses on costs, not on efficiency, in order to be able to provide all people living in terrible conditions.

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1.2 Solar radiation

The main task of this section is to do main calculations of solar insolation, relying on positions, orientations and time with respect to the Sun for further calculation of the parameters of PV systems. Solar radiation reaches the earth's surface at a maximum flux density of about 1,0 $\mathrm{kW/m^2}$ at the wavelength range of 0,3 and 2,5mm. [Michael E. Mackay, 2015]

The spectral distribution is determined by the 6000 K surface temperature of the Sun, it is also caused by radiation of a short wavelength and including the visible spectrum. Depending on the location, time and weather, solar radiation is in the range of 3 to 30 $\mathrm{MJ/m^2}$ $\mathrm{per\ day}$ at ground level. [Michael E. Mackay, 2015]

So, when solar radiation is transmitted through a cloudless atmosphere, firstly, it depends on the frequency of the radiation, and secondly, on the absorption of radiation from gases and vapors. Thus, gases (with allowance for water vapor) affect the atmosphere, raising the surface temperature of the earth at an average value of 30° C than outside the atmosphere. These characteristics of atmospheric transmittance and absorption are similar in properties to glass, so additional heat is called "greenhouse effect" and the corresponding gases are called "greenhouse gases"

In its essence, the greenhouse effect is normal property of the Earth, and a critical value for the global sustainable ecology, because, as a "normal" temperature increase, most water surfaces remain liquid. Also, the value of the greenhouse effect definitely depends on the concentration of greenhouse gases in the atmosphere, such as $\mathrm{H_2O}$ and $\mathrm{CO_2}$.

The use of fossil fuels over the past 200 years has increased the concentration of $\mathrm{CO_2}$. in the atmosphere in comparison with the level of the last millions of years. Such a change is made by the change in the radiation balance of the Earth's system. [Michael E. Mackay, 2015]

Referring to the authoritative opinion of the source IPCC (2007), such forced increase in the average temperature of the Earth's surface provoked accelerated climate change. Thus, using renewable energy sources will reduce such an impact, reducing the very likelihood of negative social and environmental consequences.

1.2.1. Components of radiation

The Sun gives enough energy to provide and sustain life on our Planet. In a time-period equaled to one hour, the Earth receives enough energy from the Sun, which covers energy needs for almost the whole year.

It will be useful to consider some properties inherent in the Sun. Firstly: the Sun consists of gases, among which hydrogen predominates. Due to massive thermonuclear synthesis, the Sun turns hydrogen into helium, and the resulting mass is converted into a source of energy according to Einstein's formula

$$E = mc^2 \tag{1.1}$$

As a result of this reaction, a constant temperature of approximately 5800 K remains on the Sun's surface, and this energy is radiated uniformly in all directions, taking into account the radiation equation of the Planck's Blackbody:

$$w_\lambda = \frac{2\pi hc^2\lambda^{-5}}{e^{\frac{hc}{\lambda kT}}-1} \tag{1.2}$$

Where

$h = 6.63 * 10^{-34}\ watt\ sec^2$ (Planck’s constant), and

$k = 1.38 * 10^{-23}$ Joules/K (Boltzmann’s constant).

W/m2, unit wavelength in meters

This equation (1.2) determines the density of the Sun's surface in units of W / m2 (wavelength in meters). For the time that this wavelength passed a distance of 150 million km to the Earth's surface, the total density of extraterrestrial energy will decrease and become a constant equal to 1367 W / m2. In Fig. 1.1 shows the graphs of the radiation formula of the black body bar for various temperatures, including the solar spectrum. (Messenger, 2003)

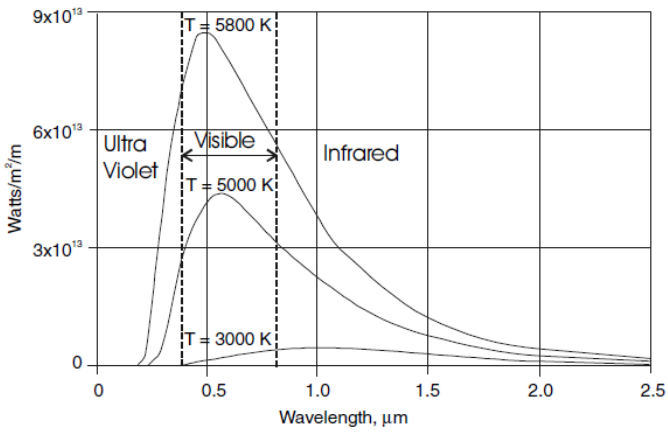

Figure 1.1 - Blackbody radiation spectra for temperatures of 3000 K, 5000 K and 5800 K.

A Sunny day means a period of time from the moment the Sun crosses the local meridian until it crosses the same meridian the next time. Taking into account that the earth rotates in a daily cycle, and also its motion is determined in orbit, the time that is needed for one revolution around the Earth is less than a Sunny day for 4 minutes.

For further calculations it is important to take into account and calculate the required number of days (DN) that correspond to a certain date. The examples of such a calculation are the EOT estimate using low accuracy and illumination algorithms at any given time.

The above-mentioned Sunny day changes throughout the year, depending on:

- ❖ The tilt of the Earth's axis relative to the plane of the ecliptic, which contains the centers of the Sun and the Earth;
- ❖ Angle, forming a vector between the Earth and the Sun for any given period of time, which depends on the position of the Earth in its orbit (figure 1.2)

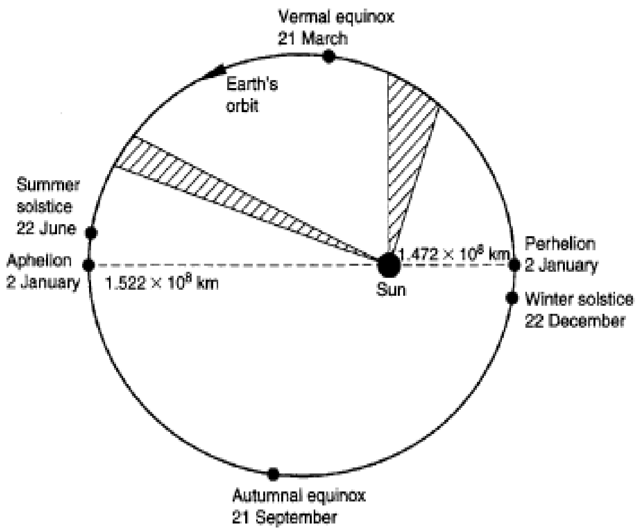

Figure 1.2 - Earth's orbit around the Sun

Thus, the standard time (recorded by a clock at a constant speed) is different from solar time. The difference between standard time and solar time is defined as:

EOT can be found from Wolfe's expression:

$$\mathrm{EOT} = 0.1236\mathrm{sinx} - 0.0043\mathrm{cosx} + 0.1538\mathrm{sin2x} + 0.0608\mathrm{cos2x} \qquad (1.3)$$

where

$$x = \frac{360(\mathrm{DN}-1)}{365} \qquad (1.4)$$

DN =1 for 1st January in any given year.

EOT can also be expressed more precisely by using the Lamm equation as:

$$EOT = \sum A_k \cos(\frac{2\pi kN}{365}) + B_k \sin(\frac{2\pi kN}{365}) \qquad (1.5)$$

where N is the day in the 4-year cycle starting after the leap year. Values A_k and B_k coefficients are given in Table 1.1. [Muhammad Iqbal, 1983]

Table 1.1 - Coefficients for equation (1.5)

k	$A_k \times 10^3$ (h)	$B_k \times 10^3$ (h)
0	0.2087	0.00000
1	9.2869	−122.29000
2	−52.2580	−156.98000
3	−1.3077	−5.16020
4	−2.1867	−2.98230
5	−1.5100	−0.23463

Solar time is such a time, necessary in the calculations of solar geometry. It is necessary to take into account the corrections caused by the difference between the longitude of a given location (LONG) and the longitude of the standard meridian of time ΔT_GMT. This correction must be taken into account in addition to the above EOT. Thus, we have that:

$$\text{AST} = \text{standard time (LCT)} + \text{EOT} \pm [(\Delta T_{\text{GMT}} - \text{LONG})/15] \quad (1.6)$$

All elements of the equation must have units of measurement in hours. The algebraic sign that is in the formula before the brackets with the longitude expression must be taken into account as a positive value for longitude, which lies east of ΔT_GMT and vice versa

1.2.2. The orbit and rotation of the Earth

The rotation of the Earth around the Sun occurs once a year in an elliptical orbit in this focus and therefore the distance from the Sun to the Earth can be expressed by the equation:

$$\mathrm{d} = 1.5 * 10^{11} \left\{1 + 0.017 \sin\left[\frac{360(n-93)}{365}\right]\right\} m, \quad (1.6)$$

where n means the day of the new year, starting on January 1.

The earth, in its turn, rotates around its polar axis once a day. The polar axis is inclined at an angle 23.45^0 with respect to the plane of the Earth's orbit. This deviation is a value that determines the position of the Sun higher or lower in the sky, depending on the season of the year. Also is the reason for long summer and short days in winter with the transition to the appropriate time.

Figure 1.4 shows the orbit of the Earth around the Sun with the dip of the polar axis. It is important to note that the first day of the Northern Hemisphere is summer, the Sun appears vertically above the Tropic of Cancer, which gives a value of latitude 23.45^0 N of the equator. And also note that on the first day of winter, the Sun will be vertical above the Tropic of Capricorn, which displays a value of 23.45^0 S of the equator. On the first day of spring and the first day of autumn, the Sun is directly above the level of the equator. From autumn to spring, the Sun is south of the equator and from spring to autumn the Sun is north of the equator. (Messenger, 2003)

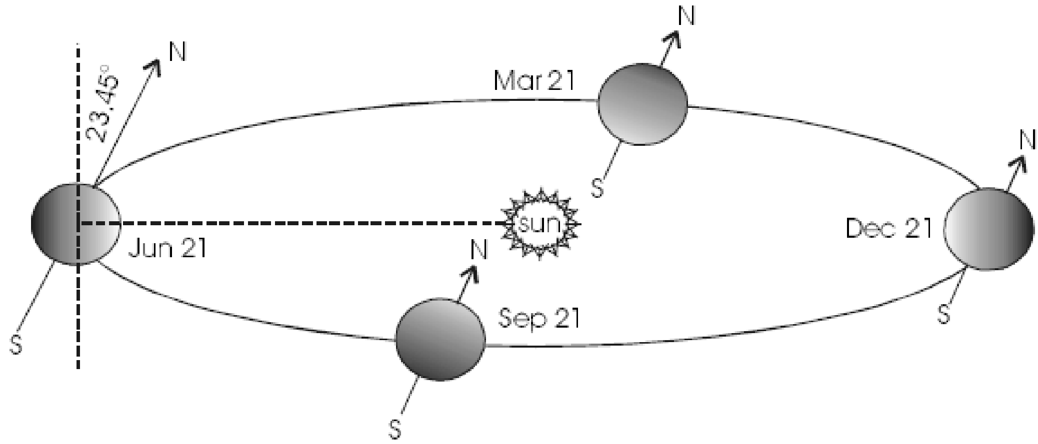

Figure 1.4 - The orbit of the earth and the declination at different times of the year.

The value of the angle of the Sun's deflection right above the equator is called the deviation, which is denoted as δ. If the angles of the north from the equator are determined as positive, and the angles of the south from the equator are defined as negative, then on any day of the year (n), the deviation δ can be expressed from the equation

$$\partial = 23.45^0 \sin[\tfrac{360(n-80)}{365}] \qquad (1.7)$$

This formula is only an approximate calculation, so it is important to take into account that not all years are important in 365 days, which means that the 80th day of the year does not always fall on the first day of spring. Despite this, the deviation is an important parameter for further calculations of the Sun in the sky at any given time of the day, season and location.

Zenith is a perpendicular line directed to the Earth (straight up), and the zenith angle θ_z – is the angle between the Sun and Zenith. The deviation may be due to the angle of Zenith, and it is also important to note that the Sun is at the highest point in the sky precisely in Sun noon.

Sunny noon is determined by time for 12 hours of the day only at one longitude (L1) in any time zone; at a longitude east of L1, the Sunny midday will be determined by the time until 12 noon of the day and at a longitude west of L1, a Sunny noon will be determined after 12 noon. (Messenger, 2003)

As a rule, it is not difficult to determine the longitude, because it is known that in time the Earth turns around in 24 hours, and also passes the path to 360^0 of the whole period; this means that it rotates at an angle equal to $15^0/\text{hour}$. It is also convenient that the zero longitude corresponds to the noon hours on a Sunny midday. All in all this means that the Sunny midday will be a multiple of 15^0 East or West longitude. Also, taking into account the fact that every hour on time is 15^0 the angle of rotation, it is easy to determine the solar noon of intermediate length.

As an example, we can illustrate such a situation that in the longitude 80^0 west, it can be noted that 80^0 is located between 75^0 and 90^0, in which the Sunny midday is defined as the noon hour by standard time. Since 80° is west of 75^0, when the Sun is directly south at 75^0, the Sun will be east of south at 80^0. The clock time at which the Sun will be south at 80° (solar noon for 80°) thus can be expressed as

$$t = 12 + \frac{80-75}{15} * 60 = 12 + 20\text{min} = 12:20\ \text{p.m.} \tag{1.8}$$

It should be noted that at a standard time relative to the time zone for which the solar noon is determined at 80^0 W. But if 90^0 W is taken as the standard of the Sunny noon, then the solar noon at 80^0 N will be determined in a period of up to 40 minutes to midday.

One glitch in the solar noon argument involves those unique locations on the Earth such as Newfoundland, Canada or India, where there is only half an hour shift between adjacent time zones, or Alaska, where a single clock time zone covers nearly 30^0 of longitude.

Proceeding from the fact that the Sun is located directly on top of the first day of summer on a Sunny afternoon of the Tropic of Cancer, one can figure out that

$$\theta_z = \phi - \delta \tag{1.9}$$

where ϕ means the latitude or angular distance from the equator, and also that the deviation and latitude are the same, and the zenith angle is zero. It should be noted that this ratio is satisfied for given latitude on a Sunny afternoon, because both the values of ϕ and δ are constant for any given day at any place. It is also important, based on the fact that time is different from a Sunny afternoon, it is likely that the Sun will no longer be directly above, and hence the zenith angle will not be zero.

Expression 1.9 can be used to find the highest point in the sky, which the Sun reaches on any given day of the year at any given latitude. It will also be true when determining that the highest point of the Sun in the sky will be like:

$$\theta_z = \phi - 23.45^{0}{}' \tag{1.10}$$

And also the lowest point in the sky will be defined as:

$$\theta_z = \phi + 23.45^{0}{}' \tag{1.11}$$

At provided that $\phi > 23.45^0$;

If $\phi < 23.45^0$, than θ_z will be negative for a certain time of the summer. It simply means that the Sun will manifest itself north of the direct direction from above in the Sunny midday. The ratio of θz, ϕ and δ is illustrated in Figure 1.5

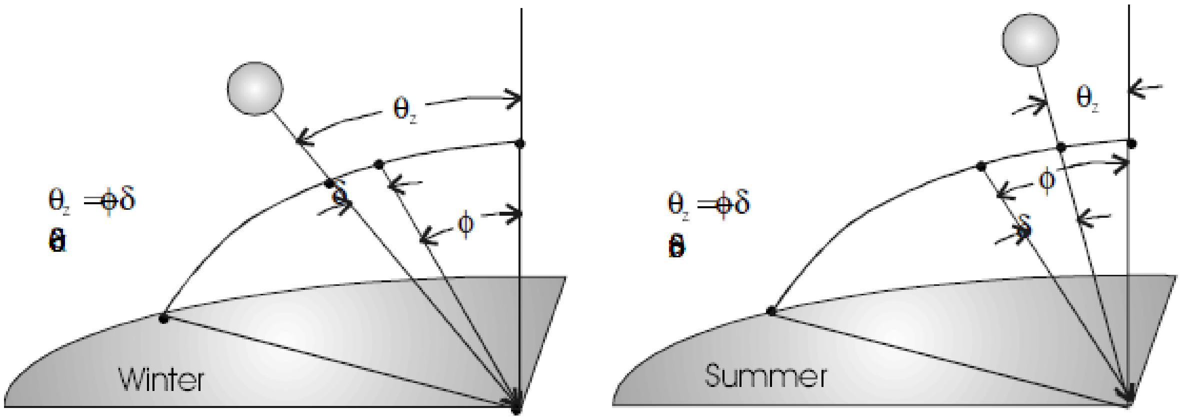

Figure 1.5 Relationships among θ_z, ϕ, δ and at solar noon in winter and summer.

1.2.3 Tracking the Sun

In order to indicate the position of the Sun, it is necessary to use three coordinates, but provided that the distance from the Sun to the Earth is a constant, the position of the Sun can be designated by two coordinates. Two common options are: solar altitude and azimuth

The addition of the zenith angle θ_z, is called the solar altitude α and represents the angle between the horizon and the incident solar ray in the plane, which is determined by the zenith and the Sun (figure 1.6).

The deviation of the angle from the Sun from the direct direction of the south can be described in the form of azimuth angle ψ, which measures the angular position of the Sun of the east or west from the direction of the south.

It is the angle between the intersection of the vertical plane determined by the observer and the Sun with the horizontal and the horizontal line facing directly south from the observer, assuming the path of the Sun to be south of the observer and this angle equals zero at solar noon and increases toward the east.

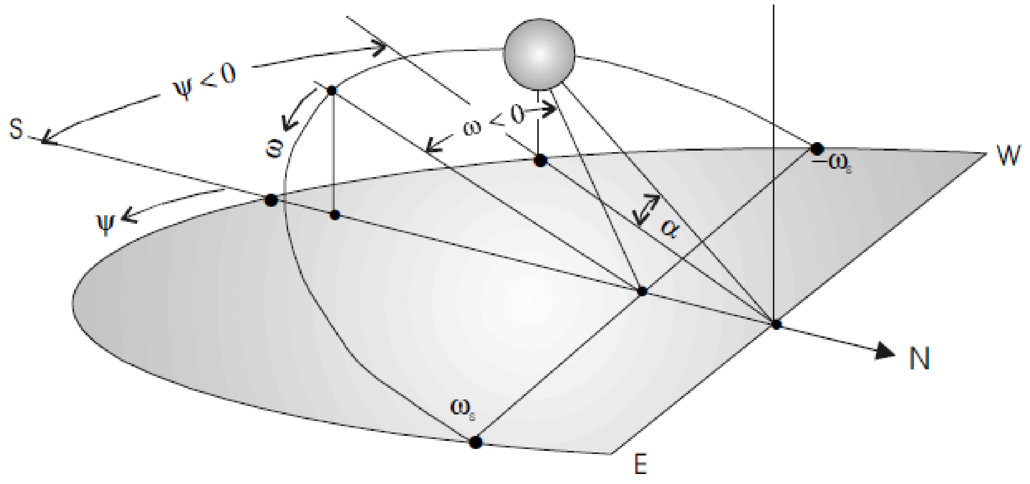

Figure 1.6 - Sun angles, showing altitude, azimuth and hour angle

It is also important to note one more angle necessary for describing the angular displacement of the Sun from the Sunny midday in the plane of visible motion. The hour angle is the difference between noon and the required time of day in the recalculation by 360^0per day. It can be expressed as follows:

$$\omega = \frac{12-T}{24} \times 360^0 = 15(12 - T)^0 \tag{1.12}$$

where T expresses the defined time of the day to solar midnight per 24 hours. For example, for T = 0 or 24 (midnight), $\omega = \pm 180^0$ and for T = 9 a.m., $\omega = 45^0$. By relating, ω to the other angles previously discussed, it is possible to show that the Sunrise angle is given by

$$\omega_s = \cos^{-1}(-\tan\phi \tan\delta) \tag{1.13}$$

Which, in its turn, implies that the Sunset angle is given by ω_s. This formula is useful in that it allows us to determine the number of hours on a certain day at a certain latitude, and that the sun is above the horizon.This formula is useful because it allows you to determine the number of hours on a certain day at a certain latitude, and that the sun is above the horizon.

Converting the Sunrise angle to hours from Sunrise to solar noon, and then multiplying by 2 to include the hours from solar noon to Sunset, yields the number of hours of daylight to be

$$DH = \frac{48}{360} \times \omega_s = \frac{\cos^{-1}(-\tan\phi \tan\delta)}{7.5} \tag{1.14}$$

Two very important relationships among β_s and ψ can be determined by using trigonometry. If δ, ϕ and ω are known, then the position of the Sun, in terms of α and ψ at this location at this date and time, can be determined from:

$$\sin\beta_s = \sin\delta \sin\phi + \cos\delta \cos\phi \cos\omega \quad (1.15)$$

$$\cos\psi = \frac{\sin\alpha \sin\phi - \sin\delta}{\cos\alpha \cos\phi} \quad (1.16)$$

It should be noted that the angles in the above expressions are measured in degrees.

Proceeding from the fact that the expressions (1.15) and (1.16) are somewhat complicated for understanding and visual perception, it is more convenient to imagine a graph of the dependence of these quantities such as α and ψ for determining the latitudes and seasons. Figure 1.7 shows a series of sections in height and azimuth at latitude of 30N. These curves show approximately how high the Sun will be in the sky at a certain time of day, during a certain month, and also with the azimuth angle that determines the time of day.

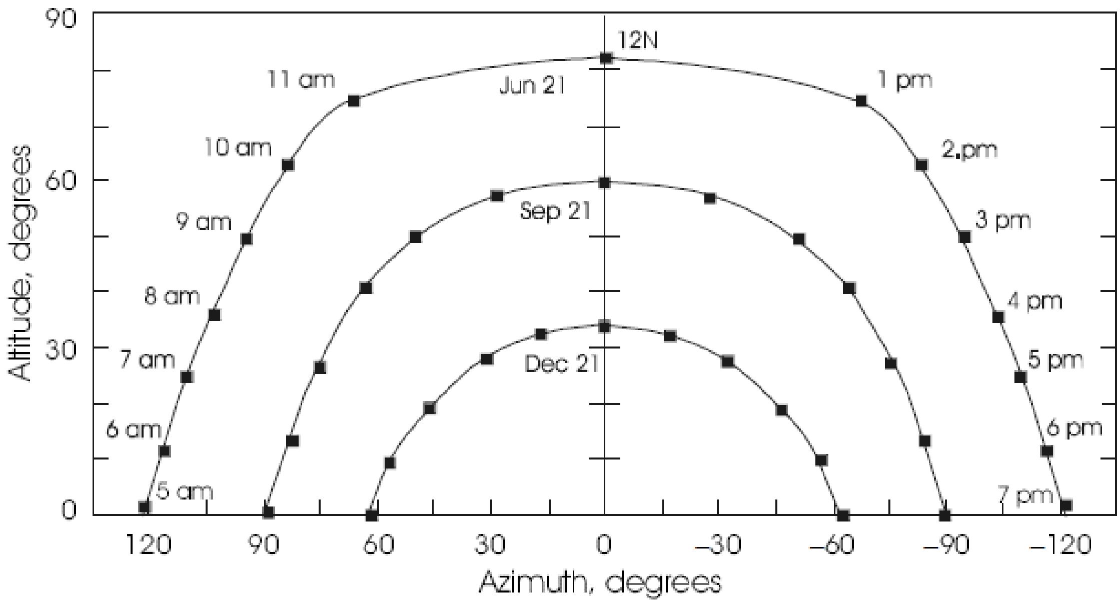

Figure 1.7 Plot of solar altitude vs. azimuth for different months of the year at latitude of 30 N.

1.2.4 Maximizing irradiation on the collector

The designer of any system that collects solar radiation must take into account the decision about the means of mounting the system. Perhaps the easiest way to install it is to install it in a horizontal position. This orientation of the system probably does not optimize the collection, because, the component of the radiation beam is proportional to the cosine of the angle between the incident beam and the normal of the collector plane, as seen in Figure 1.8.

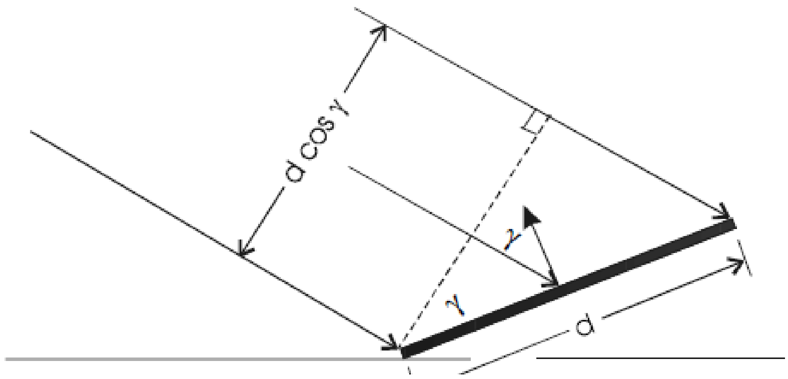

Figure 1.8 - Two-dimensional illustration of the influence of the slope of the collector on the effective area is represented by the radiation component of the radiation.

Depending on the ratio of diffuse to radiation, some of the energy received will be between cosγ and unity. However, in a strong diffuse environment, the radiation will be only a small part of the global radiation. Equation 1.9 shows that if the collector is installed in a plane perpendicular θ_z on a Sunny afternoon, it will also be perpendicular to the Sun on a Sunny afternoon. This is the point at which the Sun occupies the highest position in the sky, resulting in the shortest path through the atmosphere and the lowest air mass for a given day.

Proceeding from the fact that the Sun rotates at an angle 15^0 per hour, it will be close to the perpendicular of the collector for about several hours. And this time, the intensity of Sunlight will decrease due to the increase in the air mass of air, and the angle between the incident and Sunlight and the normal to the collector will increase.

These two factors cause the energy to decrease relatively quickly, collected by the collector, in hours before 10 am and after 14 hours. Figure 1.9 shows the approximate cumulative radiation received under the slope of the collector at an angle of latitude in which the radiation beam component is significantly larger than the diffuse or albedo component

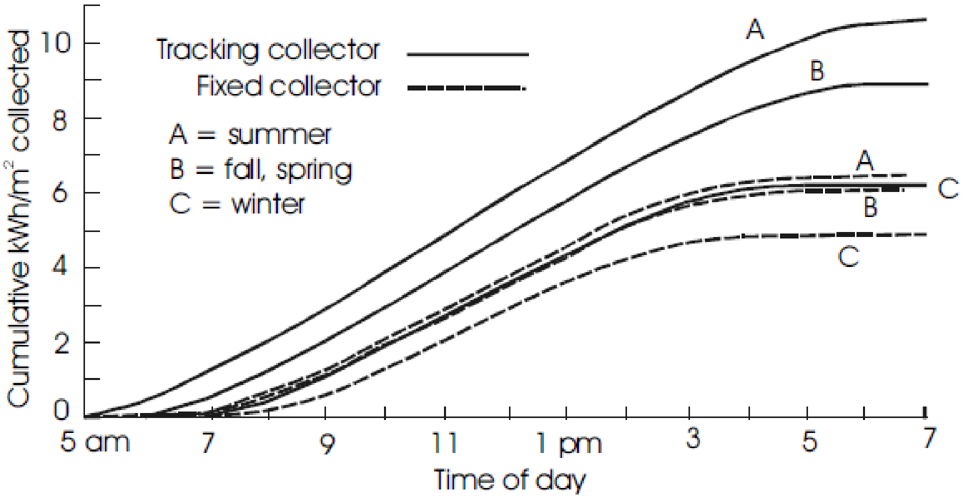

Figure 1.9 - Cumulative daily irradiation received by fixed and tracking collectors for different seasons, direct beam contribution only.

If the collector is installed so that it is able to track the Sun, then the incident illumination depends only on increasing the mass of air when the Sun approaches the horizon line. Figure 1.9 also shows additional cumulative radiation under a direct beam, which is collected by a tracking collector. Approximately 50% more energy can be collected in summer in a dry climate, using a tracking manifold. But in the winter, only 20% more energy is collected with it.

For a more interesting installation of the system, one may ask about the consideration of a single-axis tracking manifold, which is set by rotation about an axis fixed relative to θ_z. In the future, you can consider the attachment option, which can be adjusted several times a month (year). Each of the proposed options makes it possible to obtain energy, which is somewhere between an optimized fixed collector and the result of a 2x axial tracking device. It is also important to note that different places show different results relative to monthly indicators, depending on local weather and seasonal behavior.

1.2.5 Angle between beam and collector

This ratio of the angle to the collector can be obtained using geometry, which gives the equations necessary for solar modeling:

$$cos\theta = (A - B)\ sin\delta + [Csin\omega + (D + E)cos\omega]\ cos\delta \qquad (1.17)$$

Where

$A = sin\phi\ cos\beta$

$B = cos\phi\ sin\beta\ cosy$

$C = sin\beta\ cos\gamma$

$D = cos\phi\ cos\beta$

$E = sin\phi\ sin\beta\ cos\gamma$

$$cos\theta = cos\theta_z\ cos\beta + sin\theta_z sin\beta \cos(\gamma_s - \gamma) \quad (1.18)$$

Where

Angle of incidence θ: angle between solar beam and surface:

Slope β: the angle between the plane surface in question and the horizontal. In either hemisphere: for a surface facing towards the Equator $0 < \beta < 90^0$, for a surface facing away from the Equator $90^0 < \beta < 180^0$;

Surface azimuth angle γ*:* projected on the horizontal plane, the angle between the normal to the surface and the local longitude meridian. In quite different hemisphere for a surface facing due south $\gamma = 0^0$, due north $\gamma = 180^0$, westwards $\gamma = 0^0$ to 180^0, eastwards $\gamma = 0^0$ to -180^0.And for any horizontal surface is $\gamma = 0^0$.

Sun (solar) azimuth angle γ_s: projected on the horizontal plane, the angle between the solar beam and the longitude meridian. Sign convention as γ. So, on the horizontal plane, the angle between the beam and the surface is $(\gamma_s - \gamma)$ [John Twidell, 2015]

For special geometries of values, the complex formula (1.17) is greatly simplified, since, for example, for a collector that is oriented to the equator, with a slope β equal to the latitude ϕ, ($\gamma = 0, \beta = \phi$ in northern hemisphere; $\gamma = 180^0, \beta = -\phi$ in southern hemisphere), equation 1.17 reduces to

$$cos\theta = cos\omega\ cos\delta \quad (1.19)$$

For a horizontal plane, $\beta = 0$ and equation (1.17) reduces to

$$cos\theta_z = sin\delta\ sin\phi + cos\phi\ cos\omega\ cos\delta \quad (1.20)$$

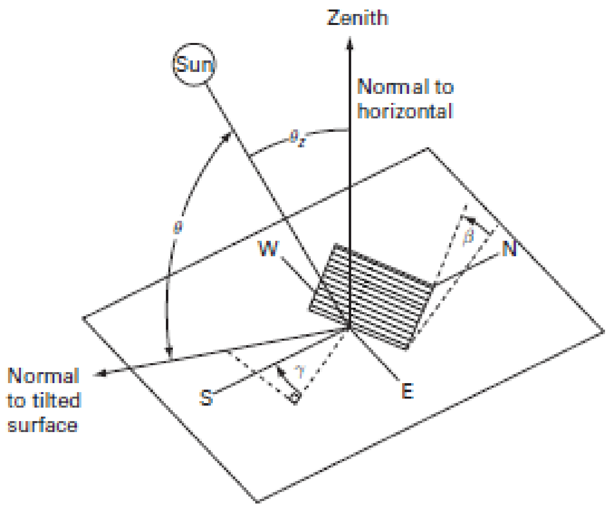

Figure 1.10 - Zenith angle θ_z, angle of incidence θ, slope β

And azimuth angle γ for a tilted surface.

1.2.6 Clearness index

The focusing of the ray component of the incoming radiation depends mainly on the cloudiness and dustiness of the atmosphere. This effect is associated with the brightness index K_T, which is the ratio of radiation on a horizontal surface over a period (usually a day or a month) to radiation, obtained on a parallel extraterrestrial surface for the same period:

$$K_T = \frac{G_h}{G_o} \qquad (1.21)$$

where G_0- extraterrestrial irradiance [W/m^2], which can be described by the formula:

$$G_0 = 1367(1 + 0.033\cos(\frac{2\pi n}{365})) \qquad (1.22)$$

Where n is number of day un the year;

Even with a clear sky, extraterrestrial insolation is reduced by diffusion and aerosol absorption, so even with an air-to-mass ratio of m = 1, the instantaneous value $K_T \approx 0.8$. This suggests that even with an absolutely clear sky there is a possibility of significant radiation scattering. Figure 1.11 is a graph of the hourly share of diffuse irradiation at ground level before total irradiation versus the clarity index. [John Twidell, 2015]

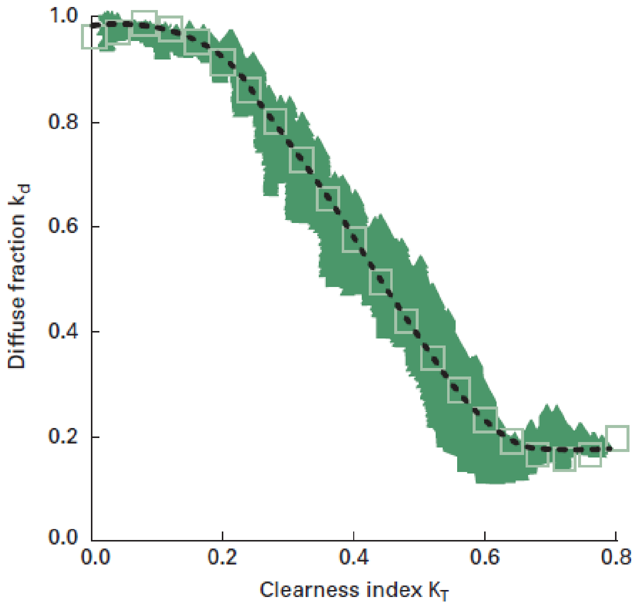

Figure 1.11 - Fraction of diffuse irradiation plotted against the Clearness Index for a wide range of hourly field data.

Based on such values, we can conclude that:

- ❖ Diffuse radiation will always be in the presence of an absolutely clear sky;
- ❖ The minimum diffuse part of the radiation will be from 16 to 20% (which cannot be focused);
- ❖ Devices need a climate with a large proportion of clear days.

1.2.7 The Olmo model for global radiation

Sunlight reaching the earth's surface without dispersion is called direct radiation (G beam). Scattered Sunlight is called diffuse radiation (G diff), and the sum of all the components of Sunlight is defined as global radiation (G global). (Messenger, 2003).

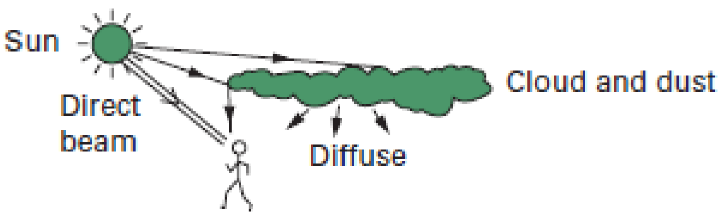

Figure 1.12- Origin of direct beam and diffuse radiation.

It is also important to note that even on a clear day, there is always at least 10% of the scattered radiation from the molecular radiation. The ratio between beam irradiance and the total irradiance thus varies from about 0.9 on a clear day to zero on a completely overcast day.

The Olmo model was developed to determine global radiation on inclined surfaces using the original data. In the following it will be indicated that the calculations were carried out with the possibility of changing the slope of the system (with any step, for example 10^0), and azimuth (with any step, for example 10^0). [Enrique Ruiz, 2002]

In the event that there are no earth reflections, the Olmo model determines the global radiation G_{tilt}, which falls on the inclined surface and also taking into account G_{hor}, falling on the horizontal surface under any conditions of sky clarity, using the equation:

$$G_{tilt} = G_{hor} \exp[-K_T(\theta^2 - \theta_h^2)] \quad (1.23)$$

where θ (in radians) - the scattering or the angle of incidence, that is, the angle between the normal to the inclined surface and the vector between the Sun and the Earth;

K_T – clearness index or the global value of extraterrestrial horizontal radiation, which takes into account the influence of conditions, cloudiness and clarity of the sky;

θ_h - angular distance (in radians) between the direction of the normal to the horizontal plane and the position of the Sun, which reduces θ_h to the solar zenith angle β_s.

$$cos\theta = \sin(90^0 - \beta)\sin(90^0 - \beta_s) + \cos(90^0 - \beta)\cos(90^0 - \beta_s)\cos(\gamma_s - \gamma) \quad (1.24)$$

Where β represents the zenith angle and γ the azimuth of a patch in the sky;

To take into account the radiation reflected from the earth, the Olmo model includes a new factor, which is described by the formula:

$$F_c = 1 + \rho sin^2(\frac{\theta}{2}) \quad (1.25)$$

Where ρ is albedo of the underlying surface, which is determined from 3 to 95%, depending on the dryness or humidity of the climate, cloudiness, snowiness or deserts of the terrain? Examples for the support of the albedo value can be found in Table 1.2 and 1.3.

Table 1.2 Albedo for soil covers

Soil	Albedo (%)
Black earth, dry	14
Black earth, moist	8
Grey earth, dry	25–30
Grey earth, moist	10–12
Ploughed field, moist	14
White sand	34–40
River sand	43
Light clay earth (levelled)	30–31

Table 1.3 Albedo for natural surfaces

Surface	Albedo (%)
Fresh snow cover	75–95
Old snow cover	40–70
Rock	12–15
Densely built-up areas	15–25
High dense grass	18–20
Sea ice	36–50
Water surfaces, sea	3–10
Lawn: high sun, clear sky	23
Lawn: high sun, partly cloudy	23
Lawn: low sun, clear sky	25
Lawn: overcast day	23
Dead leaves	30

Thus the mathematical expression for horizontal global radiation, including radiation reflected from the earth, becomes:

$$G_{tilt} = G_{hor}\, F_c \exp[-K_T(\theta^2 - \theta_h^2)] \quad (1.26)$$

So the above-mentioned model describes the estimation of global radiation on inclined planes. For calculations, it is necessary to know the horizontal global radiation, the position of the azimuth of the Sun and height as input parameters. [Enrique Ruiz. 2002]

1.3 Photovoltaics system and algorithm of calculations of PV modules

1.3.1 Photovoltaic modules

Solar modules consist of solar cells. PV systems convert solar radiation into electricity. Based on the fact that a solar cell unit cannot provide enough energy to meet all the needs, it is necessary for most applications to assemble the elements into solar modules in order to produce more energy.

Based on the fact that a typical solar cell produces less than 3 W per DC, which is approximately 0.5 V, the element must be connected in series or in parallel depending on the configuration in order to produce enough power in the future application. Figure 1.3.1 illustrates the elements assembled in modules and connected to arrays. The output peak power of the module can be from several watts and more than 300 watts depending on the proposed application. (Messenger, 2003)

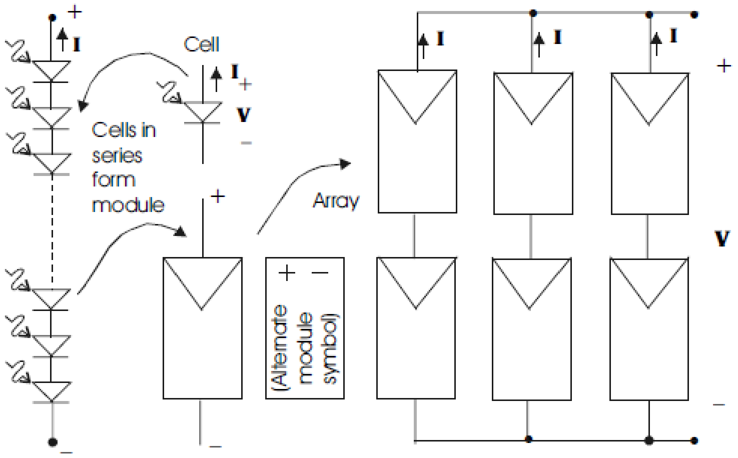

Figure 1.3.1 - Cells, modules and arrays.

Solar modules (or photoelectric modules) are produced in various types and sizes. The most common are silicon photoelectric modules with a power of 40-160 W (peak power, that is, power 40-160 W at bright Sun). Such a solar module has dimensions from 0.4 to 1.6 m^2 (Germanovich, 2014)

Solar panels can be connected to each other in solar panels (arrays) in order to get more power. For example, if you connect 2 modules of 50 W, you can assume that it will be equivalent to a module with a power of 100W. The efficiency of available modules varies between 5-15%.

(this means that 5-15% of the amount of energy falling on the solar cell will be produced in electricity). (Germanovich, 2014)

Research laboratories around the world are developing new materials for solar cells with a higher efficiency (up to 30%). It is also important to consider the cost of production. Some new technologies (like thin-film) allow producing a solar cell on a large scale, which will reduce the cost of elements and modules.

If it is necessary to obtain a high voltage or current than can be obtained from one module, then the elements should be connected to arrays. Sequential connection of the elements leads to high voltages, while parallel connection leads to higher currents. When the modules are connected in series, it is important that the maximum output of power is at the same current. Also, with parallel connection, it is important that the maximum output power is at the same voltage.

Figure (1.3.2) shows two general module configurations. Figure (1.3.2 a) shows a series-parallel connection. In the parallel connection of the figure (1.3.2a), the fuses are connected in series in each line of the module series, so that if any line fails, the excess current will go through the remaining lines, bypassing the idle line due to the fuse

Figure (1.3.2 b) shows how the modules are connected to produce both positive and negative voltage relative to the ground. If there is a connection of three sets of modules, so the combined output supplies the input signal to a three-phase inverter system.

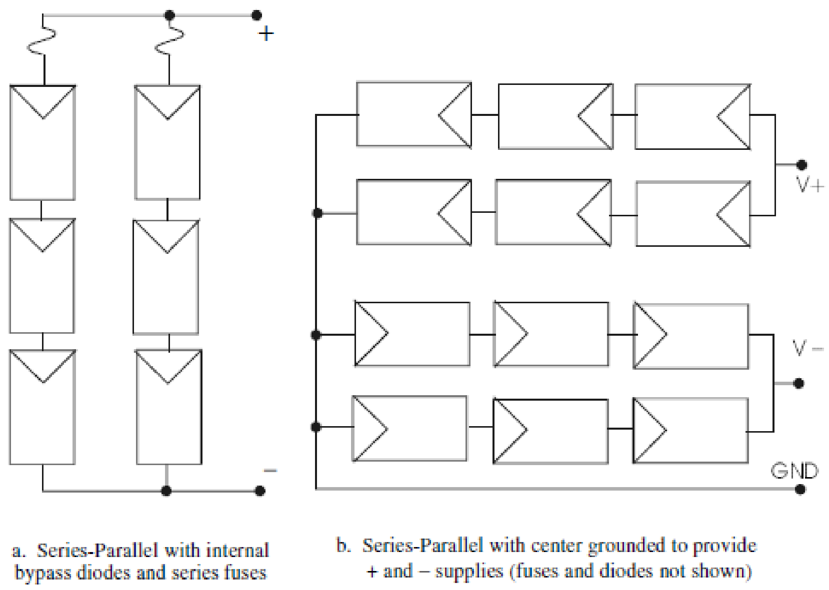

Figure 1.3.2 - Examples of PV arrays.

It is important to note that the efficiency of the module is determined by the weak link in the circuit. Since the elements are connected in series, it is important that the elements are positioned as close to each other as possible. Otherwise, the elements will work with maximum efficiency; others may not be optimized at all.

1.3.2 Life time of a solar battery

Based on the fact that photovoltaic modules produce power only in Sunlight, for PV systems it is necessary to use the energy storage mechanism, such as batteries or rechargeable batteries, whose energy can be used at a later time. In addition to the accumulation of energy, the batteries also provide a transient voltage stabilization system.

When the energy storage mechanism in the battery is executed, the system's charging controller is usually also turned on, from which the batteries can reach either the over-load state or the over-charge state. It is also possible that all or some of the loads that are in the system can be variable loads. In this case, an inverter will be required to convert the DC current into an alternating current in the array of the photoelectric element.

If the module also includes a backup system and if the system does not produce an adequate amount of energy then it is necessary to connect the controller to control the backup system. [V. Germanovich, 2014]

Solar batteries have been tested in the field on many installations. Practice has shown that the service life of solar batteries exceeds 20 years. Photovoltaic stations operating in Europe and the USA for about 25 years have shown a reduction in the power of the modules by about 10%. Thus, we can talk about the real life of solar monocrystalline modules for 30 years or more. Polycrystalline modules usually work for 20 years or more. Modules of amorphous silicon (thin-film, or flexible) have a service life of 7 (the first generation of thin-film technology) to 20 (the second generation of thin-film technology) for years.

Moreover, thin-film modules usually lose 10 to 40% of power in the first two years of operation. Therefore, about 90% of the market for photovoltaic modules currently constitutes crystalline silicon modules. Other components of the system have different lifetimes: batteries have a service life of 2 to 15 years, and power electronics - from 5 to 20 years. [V. Germanovich., 2014]

1.3.3 The nominal operating cell temperature (NOCT)

When the elements are mounted in modules, they often have an antireflection coating, and then a special laminate is also added to prevent deterioration of the contacts of the module elements. The housing of the module is usually made of metal, which provides the strength of the module. When PV elements are mounted in a module, they can be characterized by having a nominal working element temperature (NOCT).

NOCT is defined as the temperature reached in the open circuit in the module when the following conditions are met:

- ✓ Irradiance on cell surface = 800 W/m^2
- ✓ Air temperature = 20°C
- ✓ wind velocity = 1 m/s
- ✓ Mounting = open rear surface.

To estimate the temperature change of the module due to the given values of the ambient temperature and radiation, it is possible to express from the following equation:

$$T_{cell} = T_{air} + \left(\frac{NOCT-20}{800}\right) \times G \qquad (1.3.1)$$

Where *G* is the insolation in W/m^2

In Figure (1.3.2) the best module operated at an NOCT of 33°C, the worst at 58°C and the typical module at 48°C.

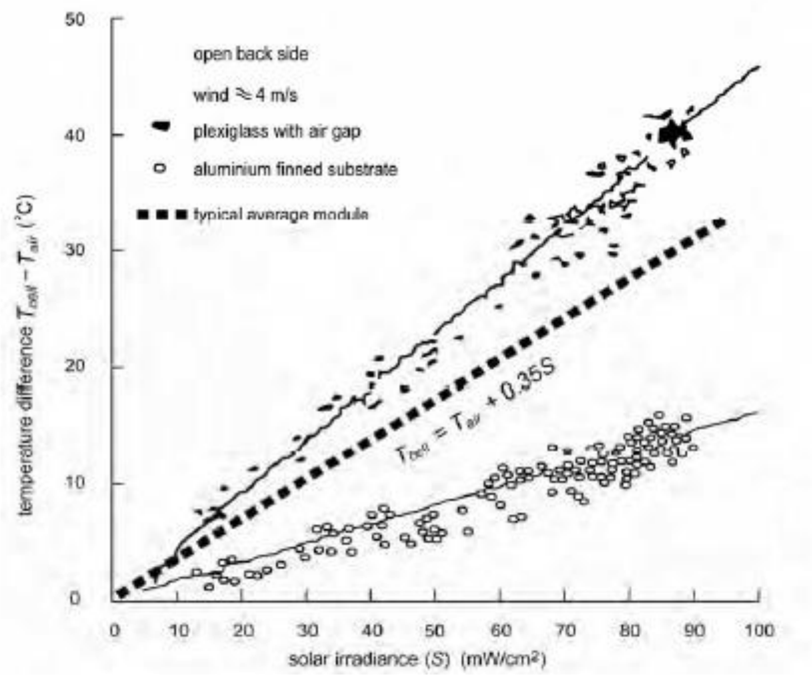

Figure 1.3.2 - Temperature increases, above ambient levels, with increasing solar irradiance for different module types

Cell packing density also has a bearing on operating temperature, with sparsely packed cells having a lower NOCT. For example:

- ❖ 50% cell packing ≫ 41°C NOCT

- 100% cell packing ≫ 48°C NOCT.

1.3.4 Inverters

Devices, such as inverters, are required when the PV is operating, in case of need of AC power. Inverters use a switching device to convert the direct current (DC) generated by the module into AC (AC), necessary to meet the needs of consumers in everyday life. At the same time, the voltage increase is usually from 12 (24 or 48) V for DC to 110 or 240 V for AC or for small systems.

Despite the different load values, inverters in autonomous systems must provide a constant voltage and frequency, and absorb reactive power in the event of loads. Also there are inverters of self-contained photovoltaic systems, which also include isolating transformers that separate the circuits of direct and alternating current.

The most used inverters in stand-alone PV systems are:

- Light duty inverters - usually a continuous output of 100-10000 W with or without frequency control. They are used to power devices such as computers and televisions.
- Medium duty inverters – usually a continuous output of 500-20000 watts, some with a "load" (automatic start and stop when the load is switched on or off). They are used for use with a wide range of small appliances and power tools.
- Heavy duty inverters – such large capacity inverters, typically a continuous power of 10,000-60,000 watts, but capable of withstanding AC overvoltage of an asynchronous motor from 30,000 to 200,000 watts.

For most similar inverters, the efficiency is 80-85% with loads in the range of 25-100% of the converter rating, but with lower loads, the efficiency can be negligible.

The inverter selection is carried out by peak load power, but not nominal. (Some consumers of electric energy have starting currents, which significantly exceed the rated current). Thus, multiplying the starting current by the mains voltage equal to 220 V, we obtain the peak power. [Stuart R. Wenham, 2007]

It is best to use an inverter with a clean sine wave at the output, especially if the load is more sensitive to the shape of the voltage, for example boilers, pumps, some electronics, etc. If there is no such necessity, and solar panels are used exclusively by lamps or other devices insensitive to voltage drop, then it is possible to do with an inverter with a rectangular voltage form, which will cost much less. It is also important to consider the possible losses of the inverter (and in the future it will be taken into account in calculations).

Preferred requirements for inverters in stand-alone PV systems are

- large input voltage range
- voltage waveform close to sinusoidal
- Tight control of output voltage (8%) and frequency (2%)
- high efficiency for low loads (>90% at 10% load)
- tolerance of short overloads, particularly for motor starting
- good behavior with reactive loads
- tolerance of loads that use half-wave rectification
- Tolerance of short circuits.

1.3.5 Output power of solar module Pmpp.

To calculate the output power, two models are usually used, one of which is linearly dependent, and the second uses a non-linear dependence of the output power on the solar radiation intensity and temperature of the solar module. [Lana S. Pantic, 2016]

The first model for calculating the output power of the solar module is as follows:

$$P_m = P_{m\,STC}\, G/G_{STC}\,(1 - \gamma(T_c - 25)) \quad (1.3.2)$$

Where P_m (W) - calculated output power,

$P_{m\,STC}$ – Maximum rated power with STC and provided by the manufacturer (W),

G - Solar radiation intensity on the plane of the module (W/m^2),

G_{STC} – Solar radiation intensity 1000 W/m^2, γ- maximum power factor correction,

T_c - Temperature of solar module

Developed in the national laboratory Colorado (USA), the second model for calculating the power of the solar module is as follows:

$$P_{max} = \frac{P_{max\ ref}\, G_T}{G_{Tref}}[1 + \alpha(T - T_{ref})][1 - \gamma(T - T_{ref})]\left[1 + \delta(T)\ln\left(\frac{G_T}{G_{Tref}}\right)\right] \quad (1.3.3)$$

Where

P_{max}(W) - calculated output power,

$P_{max\,ref}$ - Maximum rated power in the reference conditions (W);

G_T - The intensity of solar radiation on the plane of the module (W/m^2),

$G_{T\,ref}$ - Solar radiation intensity in the baseline;

T_{ref} - The temperature in the baseline (℃);

α , γ - Correction factors for temperature,

δ - correction factor for radiation.

Taking into account the found power output of Pmpp, we can also find the amount of energy produced and consider the number of modules by formula

$$E_{prod} = Pmpp \times N(100 - I_L)/100 \quad (1.3.4)$$

Where N – number of modules;

I_L- inverter losses (%);

To consider the number of modules is necessary to take into account the energy consumption per a year and per a day in the house, which can be calculated by the formula.

$$C_y = 12 \times C_m \quad (1.3.5)$$

Where C_m - consumption per month in the house;

C_y - consumption per year;

And then we can calculate the amount per a day by the formula

$$C_d = C_y/365 \quad (1.3.6)$$

In order to determine how much energy is produced by one module, it is necessary to use the formula:

$$E_{mod} = P_{nom} \times K_{exp} \quad (1.3.7)$$

Where K_{exp} – solar exposure coefficient

Now knowing what consumption per day is and how much energy the module produces, we can determine the number of modules needed to provide electricity consumption in the house:

$$N = 1{,}12 \times C_d/E_{mod} \quad (1.3.8)$$

Taking into account the price for electricity, considering the Euro per kW, as well as, energy consumption per month and the obtained values by the number of modules, we can calculate the cost of the entire system and some economic parameters by formula:

$$P_s = C_m \times N \times P_{elect} \tag{1.3.9}$$

Where P_{elect} – current electricity price;

1.3.6 Performance ratio

The performance ratio (PR) is used as an indicator for assessing the effectiveness of PV installations connected to the network. Many countries have used PR as a key indicator of efficiency in constantly increasing the productivity of their plants by eliminating systemic errors and, as a result, planning the best investment decisions. [Ahmad Mohd Khalid, 2016]

The performance ratio shows the share of energy that is actually available for export to the grid after deducting energy losses and energy consumption for operation. The ratio of PR is defined as the ratio of the final system yield (γ_f) to that of reference yield (γ_r):

$$\text{Performance Ratio (PR)} = \frac{Y_f}{Y_r} \tag{1.3.10}$$

The final yield of the system γ_f is defined as the ratio of the final or actual energy output of the system to its nominal DC power. The γ_r normalize the energy produced with respect to the system size.

$$\text{Final Yield } (\mathrm{Y_f}) = \frac{\text{Final Energy Output (kWh)}}{\text{Nominal DC power (kW)}} \tag{1.3.11}$$

The reference yield (γ_f) is the ratio between total in-plane irradiance to that of the PV's reference irradiance. The PV reference irradiance at STC condition is equal to 1000 W/m^2. The reference yield is also called the Peak Sunshine Hours.

$$\text{Reference Yield } (\mathrm{Y_r}) = \frac{\text{Total in−plane irradiance (kWh/}m^2\text{)}}{\text{PV reference irradiance (kW/}m^2\text{)}} \tag{1.3.12}$$

From the formula (1.3.6) it becomes clear that its values depend on the location.

1.3.7 Algorithm of calculations of PV modules

Initially, for calculations of solar modules, it is necessary to turn to formulas for calculating the maximum radiation for a given area. Starting with the definition of the day by formula (1.4) and standard and solar time EOT (1.3) and AST (1.6), next, calculate the deviation from the Sun δ (1.7) and hour angle ω (1.12).

Based on the above mentioned data, it is possible to find the inclination and azimuth angles, using formulas (1.15), (1.16) and (1.24).

And the final step to calculate the radiation remains to turn to the Olmo model formulas and calculate the clarity index (1.21), taking into account the extraterrestrial radiation (1.22), we also find the factor taking into account the radiation reflection from the earth (1.25), and as a result we get the calculation of radiation on the inclined plane (1.26)

To calculate the solar panel itself, namely the calculation of the module temperature and output power, we use formulas (1.3.1) and (1.3.2), taking into account the selected solar panel and, accordingly, its passport data specified by the manufacturer.

2. DEVELOPMENT OF WEB APPLICATION

Creating a good site is a clear and consistent technology. Each stage of the design process contains two stages: the divergent part (expansion) and the convergent part (contraction). The stage begins with the preparation and investigation of a large amount of information, then the screening and focusing takes place. As a result, at the end of each stage, we get an intermediate result: site structure, prototype, design thinking and so on. And at the output we have the final product, ready for use. [Obuhov, 2015]

When it comes to design, then usually its appearance is implied. But on the Internet it is important to pay attention to how the site works, that is, first of all it is important to determine the goals of the site, as it will be used by visitors. To solve these problems, as a rule, meets the designer - designer, who understands the scope of the design of the user interface (UI design) and the design of the experience of interaction (UX design)

The goal of the UX designer is to create a website that is simple, enjoyable and efficient to use. The concept of user interfaces, focused on the functional organization of the site, including the specific elements of the site (buttons, links, menus, etc.) with which users solve their tasks are closely intertwined with the design of the interaction [Robbins, 2014]

2.1 The main stages of work on the project

The main stages of creating a website can be divided into 7 steps:

The Idea and the structure of the project is the development of UX strategies and search for creative concepts. That is, you need to think through the project, the main idea and objectives of the site, its structure (including the number of pages) and the main blocks:

Research (analysis of competitors and trends, search for styles). Research is a way of transforming the creative process into a technological chain of actions that lead to a certain result. When the idea of a site and its structure is determined, it is necessary to look and evaluate the sites of competitors or those that would inspire with their elements and composition.

Looking at works that can inspire, does not mean that you need to copy them one by one, you just need to look at what the modern Internet looks like in general, what is now in the trend and position itself well. [Obuhov, 2015]

The Prototype (development of custom scenarios). The prototype is a detailed plan of the web page, necessary to focus on the sense and think over the interface at the conceptual level, up to the stage of graphic design, as well as the schematic image of the blocks that make up the site, a kind of visual script. A well-designed prototype is a full-fledged skeleton of the site, on which the design is "put on".

Figure 2.1.1 is an example of a sketched sketch of a site

Also in the additional materials is a prototype of the web application. (appendix 1)

Content (search and accumulation of information). Before starting to draw a design, you need to take care of the content. It is necessary to collect all the materials that are available such as: presentations, brochures, publications. For this web application, the publications on the site were not used, since the main content is input and output of settlement values

Design (detailing, creating a visual image). At this stage, all previous stages of development are merged. Prototypes turn into a unique visual style and approach to communication, filled with content and the product finds its final appearance.

One of the design elements can be a logo, which, as a rule, is located horizontally in the menu, and should not take up much space on the screen. In the quality of the logo can act simply the name of the company, drawn by a unique branded font.

The corporate font, in turn, acts as a means of communication, because the main purpose of any site is obtaining the necessary information, and because of how good the font is chosen, the success of the whole project depends. Therefore, it is important to choose a font that corresponds to the content. [Obuhov, 2015]

The Implementation (selection of tools and control). After the layout is drawn, agreed and approved, it needs to be turned directly into a website - go to the technical implementation.

The traditional process of technical implementation consists of the following stages:

- HTML markup language. The coder first writes the code in a text editor using the HTML markup language, and then makes out the code using cascading CSS stylesheets. The result is a layout in an html format that cannot yet be edited, but you can open it in the browser.

❖ Integration of layout into the site management system (CMS). Layout turns into a template that can be filled and edited. A ready site that can be supported and in which all functionality is ready. In this web application, such a CMS is the programming language PHP and the SQL database.

The running of the project (testing and launching projects).

2.2 Elements of graphic design

2.2.1. Design composition

It is rather difficult to give a clear definition of the concept of "composition", since this concept from the field of aesthetic perception of harmony, its task is to make the work graphically expressive, and its creation is associated with experiments and various options.

Composition is the position of objects and elements when everyone is in harmony with each other and with their environment. The composition can be selected according to one's own sensations and experience or mathematically calculated. To this end, various settlement systems are used such as: the Golden Section, the Villar scheme and the Fibonacci series, distributing everything according to guides and grids. Of course, you need to know the theory for this.

Also, accurate calculations can be found in the drawing of logos and the layout of typographic publications.

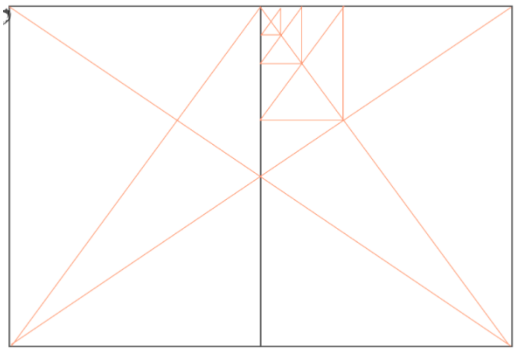

Figure 2.1.2 - the harmonious canon of Villara de Onnecura

The system that Villar has developed is known as the scheme of dividing a straight line into logical and harmonious parts consisting of a third, quarter, fifth parts and so on, indefinitely (figure 2.1.2). [Obuhov, 2015]

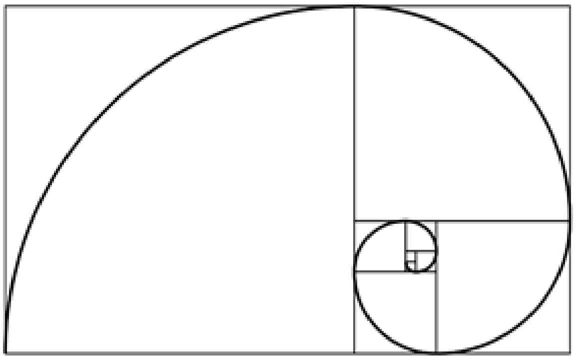

Figure 2.1.3 - The scheme of the golden section

The scheme of proportions along the golden section is shown in the figure (2.1.3). This is the ratio of the sizes when the most part refers to the smaller part, as well as the sum to the larger.

A number of Fibonacci numbers is a sequence of numbers in which each successive number is equal to the two previous ones. (figure 2.1.4) Sometimes calculations are made based on these numbers for the grid.

Figure 2.1.4 - A number of Fibonacci numbers

2.2.2 Selection of the color

No matter what the task is and how attractive the site is depicted in a sketch or prototype, the choice of color should be taken with an understanding of the task. The choice of color is a difficult task, because you need to approach the choice of aesthetics, identity and ease of use

Most modern displays can display more than 16 million colors, which means that the designer selects all possible color combinations. But do not necessarily assiduously understand the color to choose the appropriate color scheme. At the moment in the web and graphics there are many recommendations and proven theories about color, which will help to make the right choice using ready-made palettes. [Obuhov, 2015]

The psychology of color is the field of study that is devoted to the analysis of emotional and behavioral effects created by color combinations. Typically, owners of e-commerce web sites are interested in what color will be most attractive to visitors and thus bring more profit.

It is important to note and know what color solutions can affect the idea and perception of people in general, then there is a false claim that there is a single psychological response to certain colors.

It is interesting to note that many cultures have completely different associations and interpretations of the same colors. Given this observation, we can consider some general psychological associations, as most people in Western cultures react to a specific color. To do this, it is necessary to understand the technical concepts associated with the subject, that is, how colors are formed and to which categories they can be divided. The colors displayed on the computer screen are based on an additive color model. [Obuhov, 2015]

In the additional color model, the percentages of the red, green, and blue colors (RGB) of the format that are used in the web are displayed. Also there is another format that any printer uses, and also it is used in the printing house, which is displayed with the abbreviation CMYK (cyan, magenta, yellow and black). This process uses a subtractive color model, combining colors in a color model, approaching the achievement of a greyish black hue.

Unfortunately, there is no way to create a combination of only cyan, magenta and yellow, so they are always complemented by a black color, denoted. K to CMYK. Figure 2.1.5 shows additive and subtractive color models for a better understanding of these schemas.

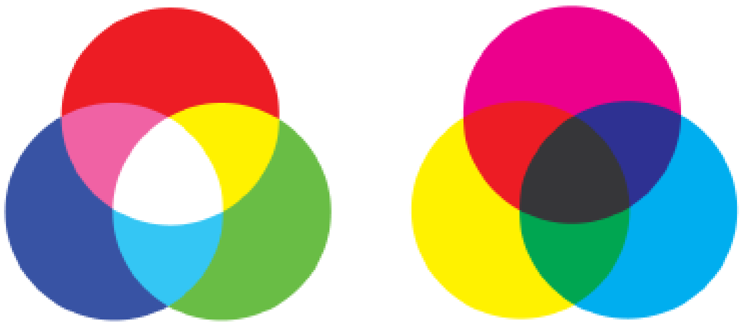

Figure 2.1.5 - RGB additive color model (left) and the CMYK subtractive color model (right)

Regardless of the purpose for which the product is designed, whether for printing or for the Internet, the lessons of traditional color theory help classify colors and group them together. The color wheel looks like an idle time, but an effective diagram designed to represent the concepts and terminology of color theory. The traditional wheel used by artists is a circle divided into 12 parts, as shown in Figure 2.1.5. Each of the presented colors is a basic, secondary or tertiary color.

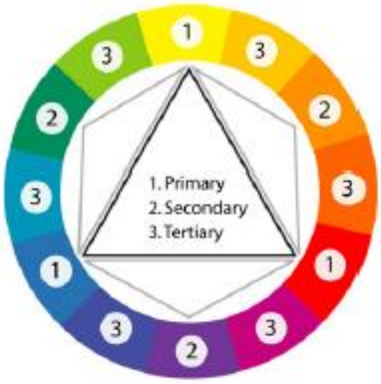

Figure 2.1.5 - The traditional red, yellow, and blue artists' color wheel

Primary colors

The main colors of the traditionally colored wheel are red, yellow and blue. These shades are shown at the corners of an equilateral triangle on the wheel, starting with the primary color, every fourth color represents another basic color.

Secondary colors

If you mix the two primary colors, you can get the secondary colors indicated in the figure by a gray triangle. The secondary colors are orange, green and purple.

Tertiary colors

Tertiary colors include: vermilion (red-orange), calendula (yellow-orange), chartreuse (yellow-green), aquamarine (blue-green), violet (blue-violet) and purple (purple).

2.2.3 Basic Typography

Typically, the main purpose of web design is communication. Even with the creation of an online store, a corporate website of the company or a profile for social networks, typography is a critical element of communication with the user.

Of course, for most people, typography is simply a set of figures, elements for creating words, sentences, and the text as a whole. When discussing the Web and selecting the font for the text that will be displayed in the browser, you need to consider a certain font family

The number of font families that are supported by default, both on the Mac and on the PC, is negligible. The suggested list of 9 font families in Figure 2.1.6 is the so-called safe fonts

Arial
Arial Black
Comic Sans MS
Courier New
Georgia
Impact
Times New Roman
Trebuchet MS
Verdana

Figure 2.1.6 - The nine “web safe” fonts that are installed by default on both Windows and Mac OS X

The main disadvantage of safe fonts is that there is a variety in each font category. If you need to select the standard font sans-serif, then you have to choose between Arial, Trebuchet MS and Verdana. For designers who develop the web, you do not need to know all the subtleties of all fonts, but given their different forms, it may seem that such a variety gives freedom of choice, except for those who know the nuances of other sans-serif fonts. For example, such fonts as Helvetica Neue, Futura and Univers.

In the language of cascading CSS styles, you can select a font-family tag that allows you to select several fonts in order of preference. This form is called a font stack. In the absence of one of the proposed fonts, the next one will be used according to the list, because each user has own list of fonts, and the user, when entering the site should see the text in any case. For example, the designer's task is to select the font Calisto MT, so it will indicate the first for the few people who have it installed. The second font is a backup plan; for this, the next font in the list, for example Georgia, will be selected. If the user does not have Calisto MT, it will be replaced by Georgia. Also Times New Roman is a close equivalent, so it can also be included in the list as an alternative. And in the end, after the final family of fonts looks like this: font-family: 'Calisto MT', Georgia, 'Times New Roman', serif; [Beaird J, 2014]

For this web application work, this combination of font families was used: font-family: 'Arvo', 'Arial', 'Georgia' sans-serif.

2.3 **Makeup of the layout (HTML5/CSS3)**

The process of layout involves the concept, on the one hand, of preparing content for publication on the Internet, and on the other, markup using HTML tags to describe the content and its functions. It is important for the web developer to understand HTML markup language and its functioning in different browsers and devices. [Jennifer Robbins, 2014]

HTML (HyperText Markup Language) is the language used to create Web page documents. HTML is not a programming language, but it is applicable to markup, so that the drawn layout with text displayed in the browser, creates a different description of the document components, such as headings, lists and paragraphs; is determined by the structure of documents.

Figure 2.1.7 – an example of HTML markup in the browser

In general, HTML tags are used to describe the structure and content of a web page, and just as the web page and its content looks, cascading (that is, including a multi-level description) style sheets that describe how fonts, background images, colors, fields and other.

Style sheets create the proper unity of design, control, and organization of document design that would not be achievable using only one HTML tool. They also allow you to display content not only in browsers, but in formats, but also on mobile devices with a small diagonal, creating the so-called adaptive design for mobile and tablet devices. [Jennifer Robbins,2014]
Cascading style sheets (CSS, Cascading Style Sheets) is a W3C standard that defines the representation of documents, written in HTML, and in general any XML language.
The representation refers to the way when document is displayed or the method of displaying it on a computer screen, on a cell phone display, printing on paper, or when reading by screen access programs. Managing the representation, using style sheets, HTML can only define the structure of the document and its content, as originally conceived.

CSS is used by the creators of web pages to specify colors, fonts, arrangement of elements and other aspects of document representation.

Figure 2.1.8 Example of adaptive designfor a mobile device

2.4 The scripts of JavaScript and library JQuery

The Javascript programming language is a scripting language that allows you to create interactivity of a web page and its behavior options, including such as:

- Checking the values entered in the form elements;
- Ability to replace styles for an item or site as a whole;
- Browser requirements to remember information and user actions;
- Create various interfaces, such as drop-down menus, scrolls;

Basically, the JavaScript language is used to manage web site elements, use styles or a browser. In addition to this language, there are other web scripting languages, but JavaScript (also still available as ECMAScript) has standards and is widely used in the web development environment. [Jennifer Robbins,2014]

In this project, the JavaScript programming language was mainly used to connect interactivity to buttons that allow you to create the effect of scrolling a web site from the first to the last page.

```
$("#js-get-started").on("click", function(e) {

    e.preventDefault();
    var mapOffset = $("#js-map").offset().top;

    $("html, body").animate({
        scrollTop: mapOffset
    }, 1000);

});
```

Figure 2.1.9 -= an example of creating scrolls in JavaScript for a site

An auxiliary element in order to facilitate the work of web development, you can use the client library jQuery, which helps you easily access the object model of the document, access the attributes and contents of the document.

The jQuery library has its own connection rule, as many components in programming, namely it should be connected at the end of the document body before the specific js file.

```
<body>
...
...
<script src="js/jquery-3.3.1.min.js"></script>
<script src="https://maps.googleapis.com/maps/api/js"></script>
<script src="js/google-maps.js"></script>
<script src="js/custom.js"></script>
</body>
```

Figure 2.1.9 is an example of connecting a library and js files.

It is important to note that this library can work both with the Internet connected, using the URL. That is, you can connect from an open Content Delivery Network (CDN), which has certain advantages in terms of its performance. In the absence of the Internet, when working on a project, it is possible to simply upload the file to a separate folder and connect it from the computer.

The map was connected using the Yandex Map API. With the help of JavaScript libraries for working with maps, it can be used and it can perform all desired manipulations.

2.5 Server-side programming, backend coding (PHP + MySQL)

A number of existing web projects, including simple web sites developed on the basis of static HTML documents and image files, also have sites with more advanced functionality, including dynamically generated pages, shopping carts (online stores), content management systems, databases and so on.

This set of functionality is supported by special applications that are run for the server side. At the moment, there are many scripts and programming languages that are used to create web applications, including such as:PHP (CakePHP, CodeIngniter, Drupal)

- ❖ Python (Django, TurboGears)
- ❖ Ruby (Ruby on Rails, Sinatra)
- ❖ JavaScript (Node.js, Rhino, SpiderMonkey)
- ❖ Java (Grails, Google Web Toolkit, JavaServer Faces)

The PHP language (Hypertext Preprocessor) is a general-purpose open source scripting language. In other words, this programming language was developed specifically for designing a web application (scripts) running on the server side.

Thus, PHP is a language that allows you to embed HTML code in the program code. Also, it is possible to use it to describe scenarios and remove a lot of text output statements and external script calls. [Dmitry Koterov, 2016]

In this paper, the PHP language was used primarily to generate queries and output information from the SQL database, as well as to work with the google map and its capabilities. On the map is an arbitrary terrain, in this case opens on the map of Estonia, and enables the user to indicate the location of his home or the desired object of calculation on the map.

When selecting a specific point, a marker is displayed on the map. This token makes a query in the SQL database that the user needs the values of the input data for the specified location. The database stores information on solar radiation data and air temperature for each of the points on the map and when requested, the data goes to the data with formulas for further calculations. The card receives data from the database in an XML file format that acts as an intermediary between the card and the database. To export information about markers from a database to an XML file, you can use PHP scripts. [Dmitry Koterov, 2016]

It's also important to note that when you recalculate data in the application itself, you cannot reload the page, but you can change the original data, such as location or further values for calculations, and get the result instantly. This approach is possible with the help of Ajax technology (asynchronous query technology), which allows you to get a new result without queries to the server and without reloading the page.

This process using Ajax can be described as follows:

- ❖ It is necessary to fill in the data;
- ❖ After each change, JavaScript checks if all the required fields are filled, and if the conditions are met, then Ajax sends it to the server in the required form;

❖ On the server using PHP, we get this data, we also make a query to the database to get the data on the locations and make calculations;

To determine the date and time, classes are used in PHP DateTime, Dateinterval, and DateTimezone and library DateTime Picker. These classes are a simple object-oriented interface for the correct creation and use of dates, times and time zones.

For this case, it's important to specify the work with dates and calendar, for which the DateTime class is responsible. The DateTime class provides an object-oriented interface to control the date and time values. As an example, you can specify the following entry:

```
< ? php
$datetime = new DateTime ( );
```

When called without arguments, the DateTime class constructor creates an instance corresponding to the current date and time. Example of calling the constructor of the DateTime class with an argument:

```
< ?php
$datet ime = new DateTime ( ' 2 0 1 4 - 0 4 - 2 7 5 : 0 3 AM ' ) ;
```

To describe the format of the calendar, you can use a different entry:

```
int GregorianToJD(int $month, int $day, int $year)
```

We can convert a date in JDC format to a string that looks like a month / date / year, which can be broken down into components to work separately. For this use the explode () function:

```
$jd = GregorianToJD(10, 11, 1970);
echo "$jd<br />";
$gregorian = JDToGregorian($jd);
echo "$gregorian<br />";
$list = explode($gregorian, "/");
mixed JDDayOfWeek(int $julianday, int $mode = 0)
```

In this project, working with large computations cannot do without an SQL database, which is a structured query language (Structured Query Language). Such a database is a set of related data stored in tables, and allows them to operate on them. SQL symbolizes the structured query language. There is a category of SQL users that use the language only to formulate queries. Therefore, working with the database, more often the user operates the server requesting and receiving data back.

The query is directly the command that is formulated for the DBMS and requires the provision of certain specified information. Such information is usually displayed on the computer display screen or the terminal used, or otherwise stored in a file and used as input for another command or process. [Martin Gruber, 2014]

2.6. Result: How does the web application work?

For the sake of clarity of the web application, it is located in Appendix 2, which will be referred to in the following to describe its operation. As can be seen from the figure (appendix 2), the website is divided into 5 blocks, which are displayed as a whole web page in the browser.

The basic principle: when a user enters, the first thing he sees is the start page where the site name, the invented logo is displayed, a small explanation for what he (the site) needs and a button to continue the action.

In the second block, a map and several data selection functions have already been provided, that is, the user can access the map or input elements to specify the required data, namely the location of interest for a certain period of time. And click on the button to continue.

In the third block, it is necessary to enter the parameters of the angle of inclination of the surface (the roof, which can be either straight or inclined) and depending on the slope of the module surface itself and the azimuth angle of the Sun's rotation. Based on the selected location and time data in block 2, the site considers the maximum radiation for the selected azimuth data and the slope angle of the surface. After that, click the button next.

In block 4, calculations are made directly on the solar panel itself based on the maximum radiation found in block 3. For additional calculations, it is necessary to enter the parameters of the panel itself (the nominal power that can be found in any passport data to the products from the manufacturer), set the value of electricity consumption in the house , the current price of electricity and possible losses in the inverter.

Based on all the set values, the program calculates and provides data on consumption per year and per day by one solar panel. Also, it provides data on energy production by one module per day. Further, it considers the number of modules (which are necessary to meet the needs of the house), and some economic parameters like the price of the energy system and the price of electricity, which is expected to be 10 years after the solar panels are connected.

In block 5, the site issues calculations for radiation, air temperature and the module, the ratio of productivity and generated energy and output power over an annual period, divided by months, and annual values are also specified.

SUMMARY

One of the objectives of the thesis was to show a review of the existing situation in the field of renewable energy, namely, to concentrate on developing additional concepts for calculating solar panels. Since a person currently lives in the information age, it is necessary for him to use the resources available to solve new problems.

Renewable energy remains a quite competitive option for replacing a fossil energy source, but even in this case, it is necessary to modernize and speed up some processes, in the frequency of calculating the maximum radiation and parameters of the solar panel itself. .

Therefore, for a given idea to accelerate the ability to read the necessary values, an online calculator model was developed to calculate the parameters of the module. Of course, it cannot be said that this idea represents something revolutionary new, but when viewed from the point of view of web design, it makes it clear that this site gives a simple calculation model, in which even a non-trained user can understand without additional explanations.

After all the task is to develop a web site that will work for ordinary people who do not need to understand the entire process in the field of engineering and electrical engineering, but will have an idea how to install a solar panel for their houses and know how many modules are needed to ensure their needs for electricity.

Renewable energy in a global sense, at present moment, does not bring much benefit, but in number of a personal houses it can be very useful, installing in your house several solar cells and a small windmill.

In this thesis, the main provisions for the calculating solar energy, using web resources are described. The description of solar energy in a whole, calculation of radiation, beginning with the study of the position of the angles of the azimuth and the angles of the inclined surface, as well as, the use of the Olmo model as the main calculations were given. And by combining this model with web technologies of design and programming, we are able to calculate the necessary parameters of the solar panel in the shortest possible time using the online calculator site.

This website is a kind of landing page, when scrolling each page, we can add and calculate additional parameters for the solar panel, starting with finding the solar radiation, additional parameters of the module.

The basic idea was to create a web page that allows anyone who needs a panel calculation for their home. Also have information on how and at what angle to install the solar module, calculate the number of panels, relying on a certain energy consumption in the house; output power and the amount of energy produced, as well as some economic parameters, such as the cost of the whole system and the price of electricity over a period of 10 years.

Like any technology, this site has its advantages and disadvantages. The merits include such a thing as the fact that it is possible to speed up the process of calculating and obtaining solar radiation data for a certain locality and a given time. But the main shortcoming is the difficulty of connecting or downloading a database from the sources of meteorological centers to obtain all these locations at a certain time, which would allow having calculations for any point on the Planet. And in fact the solution of this shortcoming is the main task for the future.

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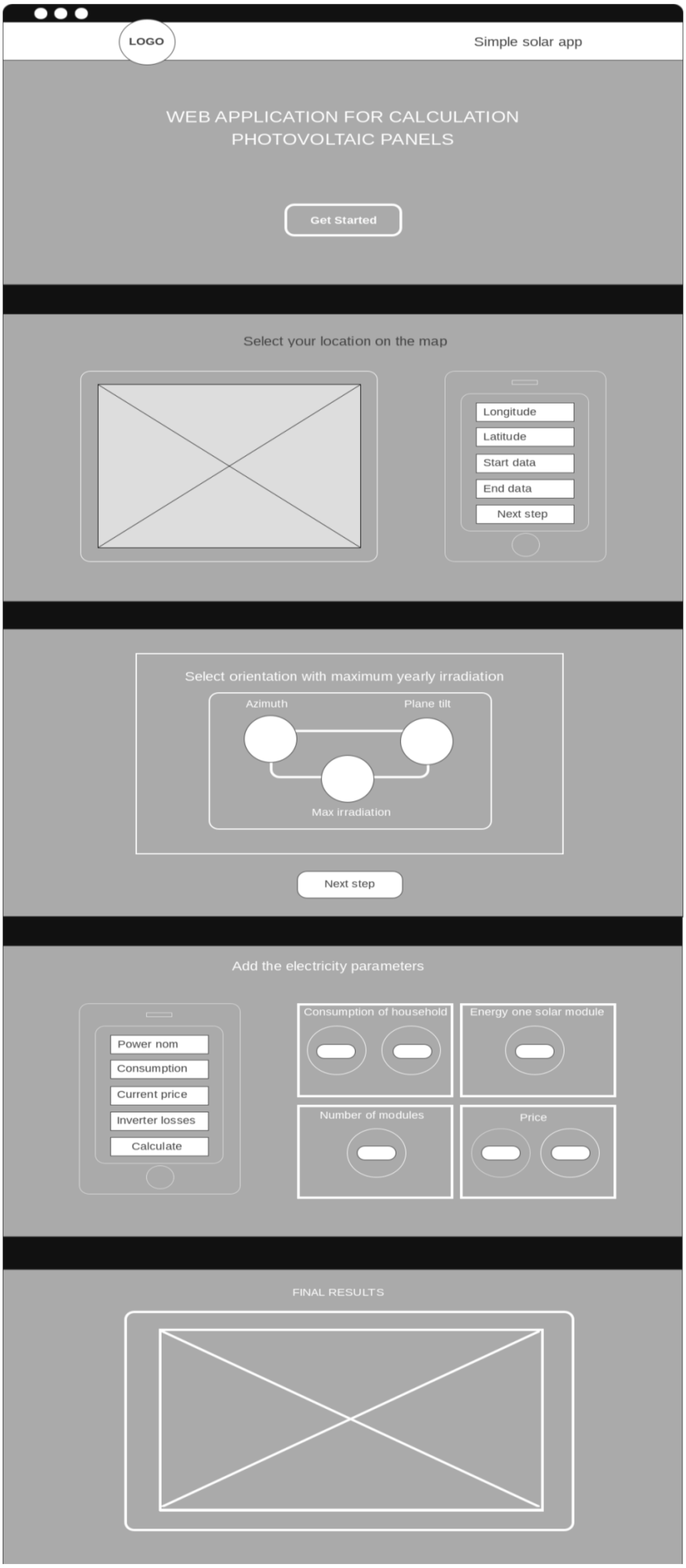
APPENDIX 1 – WIREFRAME OF WEB APPLICATION



APPENDIX 2 – COMPLETED WEB APPLICATION