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A computational software for Photovoltaic systems design focusing on building applications

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Abstract

Solar radiation energy is one of the most important energy sources with increasing penetration into the power supply systems of many countries, due to the reduced environmental impact of its operation. This study introduces a software providing a complete study of a photovoltaic infrastructure at a given location of PV grid and a specific consumption of electric power in residential buildings. The application includes all the stages of a PV installation study, starting at the location of PV grid installation, calculating the radiation, determining the electricity consumption, determining the installation self-sufficiency, selecting PV modules, identifying the inverters, the accumulators and the wiring, and, finally, of PV modules' dimensioning - placement. This computational software contributes to the science of photovoltaic technologies as new photovoltaic elements with improved characteristics can be studied and developed, because it is possible to register in software of characteristic specifications beyond the standard commercial elements.

Key Words Solarl radiation density, Photovoltaic Infrastructures, Computational Software

1. Introduction

Energy demand is increasing day by day due to increase in population urbanization and rapid industrialization (Sunanda Sinha, S.S. Chandel, 2014). The fossil fuel resources, like coal, oil and gas, have limited reserves which results in continued fuel price hike which affects the economy of any country. Renewable energy is obtained from sun, wind, biomass, water, tides, ocean waves and geothermal heat.

The Sun and its obtaining energy can be considered as the most important of the Renewable Energy Resources, because some phenomena in nature have been happening in mathematical precision for several million years. There is a wonderful cycle, a chain of events that allows life on Earth, thanks to the increase of the temperature of the soil, the air, the ocean, the evaporation and the photosynthesis. In this sequence of successive events, Sun plays the decisive role and appears to be the main factor of many of the remaining Renewable Energy Resources.

It is advisable to use and exploit the various forms in which Solar energy is transformed, since the Sun will shine for at least five billion years, and all these forms of energy will continue to exist. It will be inexhaustible and Renewable Energy Forms (Lynn, 2010).

The photovoltaic systems are direct implementations that use the solar energy in electricity. A photovoltaic installation includes photovoltaic modules, necessary transformers and voltage regulators, accumulators and wiring to form an integrated power supply system. Of particular interest are photovoltaic technologies with emphasis on residential buildings. I

The developed software is a tool for providing a complete study of a photovoltaic infrastructure at a given location of PV grid and a specific consumption of electric power in residential buildings. The application supports both stand-alone photovoltaic systems and interconnected ones.

The application includes all the stages of a PV installation study, starting at the location of PV grid installation, calculating the radiation, determining the electricity consumption, determining the installation self-sufficiency, selecting PV modules, identifying the inverters, the accumulators and the wiring, and, finally, of PV modules' dimensioning - placement. This is a very important feature of the developed software as opposed to most implementations which focus on a single parameter, such as the calculation of radiation, PV modules or frames or accumulators (Becker et al., 2013; Green et al., 2015; Yan et al., 2017).

2. The implemented software

This section presents the practical application of photovoltaic technology by developing an appropriate computational code that will allow the user to estimate the energy generated by the photovoltaic systems in given climatic, temporal and spatial conditions in order to evaluate their ability to use for the energy coverage of a building. The software developed on MATLAB computing language environment, due its effectiveness and user-friendly interface [39]. Moreover, MATLAB provides capabilities of calculations and graphic representations.

The software is split into routines providing maintenance flexibility, better control, reduce the execution time and enables scalability capabilities. The program specifications are presented in the first screen (Figure 1).

Photovoltaic Infrastructures Designing Program

The software was developed during the doctoral thesis entitled: "Investigation of solar energy applications in residential buildings focusing on photovoltaic technologies" and is a tool for providing a complete study of a photovoltaic infrastructure at a given location placement of PV frames and specific electricity consumptions in buildings for domestic use.

The application can support both autonomous photovoltaic systems and interconnected ones.

The application includes all stages of a PV infrastructure design, from the placement location, the calculation of solar radiation for the specific place, the determination of electricity consumption, the specification of energy autonomy, the selection of PV frames, the identification of inverters and convertors, the wiring, the accumulators and the dimensioning of PV modules.

A very useful feature of the implemented application is the information that the software provides to the user in the aforementioned stages.

Particular emphasis was placed on the application to provide relevant graphs that will help the designer to make his final decision.

Figure 1. Program initial screenshot.

The basic input information of the program is the geographical coordinates (Longitude and Latitude) as well as the altitude of the photovoltaic system place (Figure 2).

Geographical Coordinates & Altitude

Enter the Latitude of the area you are interested in

Enter the Longitude of the area you are interested in

Enter the Altitude (in km) of the area you are interested in

Figure 2. Geographic coordinates and altitude of the area of interest.

The developed software calculates the intensity of solar radiation at the installation place of the PV grid (Figure 3) at the worst day of the year for the study area based on decomposition model published by Erbs, Klein and Duffie (Erbs et al., 1982). The obtained results converge with existing experimental records, such as those from the Technical Chamber of Greece (Ministry of Environment of Energy and Climate Change, Technical Instruction of the Technical Chamber of Greece 20701-3 / 2010, 2010).

Calculation of Solar Energy
The Intensity of Solar Radiation in Athens is
The Intensity of Solar Radiation in Alexandroupolis is
The Intensity of Solar Radiation in Patras is
The Intensity of Solar Radiation in Heraklion is

Figure 3. Intensity of solar radiation for desired locations.

It is necessary to determine the energy autonomy of the autonomous PV systems (Figure 4). In the case of an interconnected PV system, the number of days of self-reliance is set to zero, since the energy not covered by the PV plant can be provided by the power grid. It is also recommended that the interconnected PV systems take account of a number of days of self-reliance in the event of a power cut.

System autonomy days

Self-reliance (in days) is only considered in PV storage systems. The number of self-sufficiency days occurs depending on the criticality and the type of load being fed.

System Type	**Minimum Days**	**Maximum Days**
Household electrification	5	10
External lighting system	5	10
System for agriculture and farming	5	10
Telecommunication system	10	Engineer's opinion
Signaling system	10	Engineer's opinion

Enter the PV plant self-reliance days:_

Figure 4. Determination of the number of days of autonomy PV system.

The next step is to define the slope (α) of the photovoltaic collectors (Figure 5). The system proposes the optimum angle (a), but the user can enter the desired angle according to the current conditions.

> Since the Photovoltaics will operate throughout the year and there will be a constant power consumption, the slope of the frames will be selected equal to the latitude of the area.
>
> Otherwise, you can enter the desired angle (in degrees) of the collectors (a). If you do not want to change its value you can type a negative number: The value of the collector angle will not change and will equal to the latitude of the area.

Figure 5. Optimum collector angle and azimuth angle

After the identification of the initial conditions for the photovoltaic system, the next step is to determine the power consumption in the building. The devices may be either Alternative Current (AC) or Direct Current (DC) equipment. Thus, the software examines each type of device separately. The entry of consumptions terminates when the power of the device and its time of use are zero. The total electricity power required by the PV grid is derived from the sum of the individual power consumption of AC and DC devices.
In order to reliably calculate the maximum power required to be installed in the photovoltaic grid, all coefficients influencing the performance of the modules must be determined and therefore calculate the electrical power at the output of the PV grid. These coefficients are dimensionless sizes, smaller than the unit, and are summarized in Table 1.

Table 1. Required coefficients to calculate the total demanded PV power.

Coefficient	Symbol
Daily energy requirements	E_T
Coefficient of temperature correction	σ_θ
Pollution coefficient	σ_ρ
Aging coefficient	σ_γ
Diode loss coefficient	σ_δ
Coefficient of heterogeneity	σ_α
Wiring coefficient	σ_κ
Energy transmission losses coefficient	σ_{MHE}
Overestimation coefficient	σ_{YM}

Figure 6 depicts the registration of the coefficients for calculating the total power required by the PV system, according to Table 1.

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Calculation of the total coefficient of the PV grid

Enter the average temperature (in ^{o}C) of the month with the lowest solar radiation in order to calculate the Coefficient of temperature correction:

The pollution coefficient decreases as the contamination on the surface of the PV frame increases. Indicative values for the pollution coefficient are:

σ_ρ = 0.95 for clean frames or frames that are frequently cleaned

σ_ρ = 0.90 for slightly dusty frames

σ_ρ = 0.80 for dirty or even for horizontal frames

Enter the pollution factor:

The percentage reduction of photovoltaic conversion increases by 1% for each year of grid operation. For 20 years of operation, the average aging coefficient is equal to 0.90.

Enter the aging coefficient:

The non-return diode is used in systems with storage for avoiding battery discharge through the PV modules during the night. Losses (if any) are 1%. Thus, with a non-return diode the coefficient is 0.99, otherwise 1.

Enter the diode loss coefficient:

The heterogeneity of the electrical characters of PV frames reduces the output power of an array by 2%.

Enter the coefficient of heterogeneity:

The wiring coefficient expresses the Joule loss in the connections of the PV frames. Usually, the loss values range from 1% to 3%. Larger loss rates occur after a long-term operation of the infrastructure. Typically a value of the wiring factor is equal to 0.98.

Enter the wiring coefficient:

Coefficient of power transmission losses in various types of PV installations.

Autonomous Photovoltaic Systems with storage in batteries, including:	
DC-DC converter and DC-AC inverter	0.75 – 0.80
DC - AC inverter	0.85 – 0.90
PV without battery storage, including	
DC-DC converter and DC-AC inverter	0.75 – 0.80
DC - AC inverter	0.96 – 0.98
No voltage inverter (only DC consumption)	0.99

Enter the energy transmission losses coefficient:

Error correction factor, which can range from 15% to 25%.

A large overestimation rate entails increased installation costs.

Figure 6. The coefficients influencing the performance of the PV modules.

After the entry of the aforementioned data, the software calculate the power that PV grid should provide according to following equation:

$$P_\alpha = \sigma_{YM} \cdot \frac{E_T\,[\frac{wh}{d}]\cdot P_{STC}[\frac{kw}{m^2}]}{\Pi[\frac{kwh}{m^2\cdot d}]\cdot \sigma_{\Sigma A\Phi\Pi}\cdot \sigma_{MHE}} \cdot \left(\frac{N}{N-n_{\alpha\upsilon\tau o\delta}}\right) \quad (1)$$

where,

Pa is the maximum power of the PV infrastructure in W

ET is the required total daily energy in Wh/day

Π is the available solar energy in the installation area per day in kWh/m^2.day

P_{STC} is the power density of the incident solar radiation under standard conditions STC, equal to P_{STC} = 1kW/m^2

$\sigma_{\Sigma A\Phi\Pi}$ is the product of all loss coefficients according to Table 1.

σ_{MHE} is the power transfer to the load coefficient

$n_{\alpha\upsilon\tau o\delta}$ is the predicted days of the system's self-sufficiency in the period of the worst month

N is the total number of days of the month which the system's days of self-reliance are determined.

It is noted that for PV installations without batteries the term $N/(N-n_{\alpha\upsilon\tau o\delta})$ of equation (1) is not used.

Then, the designer has to determine the technical specifications of the PV module to be used in the installation. These PV module specifications are the maximum power rating, the open circuit voltage, the short circuit current, the maximum power voltage, the maximum power current, the maximum system voltage and its dimensions.

Based on the data entered, the program asks for the PV field output voltage to be entered (VNOM_DC_PV), after having presented key requirements to be met (Figure 7).

Determination of Photovoltaic grid output voltage

To determine the voltage at the output of the PV field ($V_{NOM\_DC\_PV}$), it must first be checked that the voltage $V_{NOM\_DC\_PV}$ is not over the permissible operating limits of the next electronic device. Also, in systems containing batteries, the clue to determining $V_{NOM\_DC\_PV}$ is the input voltage of the battery charge regulator, which is inserted immediately after the PV grid.

Autonomous photovoltaic systems with energy storage in accumulators

$V_{NOM\_DC\_PV} \geq 1.2V_B$, when the infrastructure uses battery charge regulator or battery charge regulator and DC-AC inverter

$V_{NOM\_DC\_PV} = V_{CONV}$, when the infrastructure uses battery charge regulator and DC-DC converter

Interconnected Photovoltaic Systems or Autonomous Photovoltaic systems without energy storage in accumulators

$V_{NOM\_DC\_PV} = V_{INV,}$ when the infrastructure uses DC-AC inverter

$V_{NOM\_DC\_PV} = V_{CONV}$, when the infrastructure uses battery charge regulator and DC-DC converter

Figure 7. Determination of PV grid output voltage.

The software presented in this paper informs the user about the required power that the PV grid should provide and, depending on its value, suggests the use of a battery charger or intermediate inverter chargers. The critical power value is 15kWp, so under this limit a battery charge regulator is used. Since the power is greater than 15kWp, intermediate voltage inverters are used, while a battery charging regulator is not an advisable techno-economic solution. According to the required power that the PV field should provide, the user has to entry the specifications for the appropriated devices.

Once the required data has been determined, the next step is the connection of the PV modules, referring to the way they are arranged. The PV modules are connected in series, forming arrays to achieve the desired voltage that has been calculated. Also, the arrays are connected in parallel in order to achieve the maximum required power. The critical power value of 15kWp will determine the connection of PV modules. A battery charger is used, when the required PV power is less than or equal to 15 kWp, while a PV power greater than 15kWp, demands the use of intermediate voltage inverters.

The next step is to determine the specifications of the battery system for Autonomous Photovoltaic Systems (APS). At this stage, the type and basic features of the batteries, which are the nominal voltage, VB, and nominal capacity, C, as well as the maximum allowable depth of discharge (DoD) during operation of the system. The selected value for the depth of discharge of the batteries also determines their expected life span. The progressive – due to aging - decrease in the nominal capacitance value of a similar accumulator system is expressed by the aging coefficient, $\sigma_{\Gamma\Sigma}$. In photovoltaic systems desgining, the aging coefficient ($\sigma_{\Gamma\Sigma}$) for lead-acid accumulators equals to 0.8.

It is also necessary to determine the electrical connection between the batteries (series-parallel) in order to form a system of identical accumulators that will cover the load supply needs both during the night hours and during the foreseen period of self-reliance.

The selection of nominal voltage of the battery system can be achieved initially based on the maximum power of the PV field. It is clarified that the nominal voltage of the battery system should be in line with the output voltage of the charging regulator or the intermediate inverter. Otherwise, a DC-DC (converter) voltage converter will be required, which increases both the electrical losses and the total cost of the infrastructure.

After the entry of the days of self-sufficiency of the APS, the nominal operating voltage of the battery system, the depth of discharge, the aging coefficient, $\sigma_{\Gamma\Sigma}$, the power transfer coefficient and the average annual temperature (°C) of the installation area of the accumulator, the required nominal capacity (Ah) of the battery system can be determined to meet the design specifications. The nominal capacity is calculated from the equation

$$C[Ah] = \sigma_{YM} \cdot \frac{E_T[\frac{wh}{d}] \cdot (n_{\alpha\upsilon\tau o\delta} + l_D)}{\sigma_{\Gamma\Sigma} \cdot DOD \cdot V_B[V] \cdot \sigma_{MHE}} \quad (2)$$

where,

C is the nominal capacity of the battery system

σ_{YM} is the overestimation coefficient

E_T is the required total daily energy in Wh/day

$n_{\alpha\upsilon\tau o\delta}$ is the predicted days of the system's self-sufficiency in the period of the worst month

l_D is the percentage of consumption loads directly fed by the batteries, as opposed to those fed directly from the PV field (takes values between 1 and 0)

$\sigma_{\Gamma\Sigma}$ is the aging coefficient of batteries' system

DoD is the depth of discharge

V_B is the nominal voltage of batteries' system

σ_{MHE} is the electric losses coefficient of the batteries' system to loads

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Calculation of Battery System for Autonomy Photovoltaic System (APS)

Calculating Depth of Discharge Battery System

The depth of discharge depth (DoD) of a battery depends on the system's energy requirements and the type of electrode reaction. In the APS designing, the selected depth of discharge values range from 40% to 50%.

Autonomy Days of APS	Depth of Discharge of battery system
1 – 3	30% - 40%
4 – 6	50% - 60%
7 – 10	70% - 80%

Enter the depth of discharge of the accumulator system:

The percentage of loads directly fed by the batteries, as opposed to those fed directly from the PV field, is expressed by the factor l_D. The l_D coefficient equals to 0 when consumption loads are fed directly from the PV field and the limit value 1 when all consumption loads are fed by the battery system.

Enter the l_D coefficient (0...1]:

The power transmission coefficient from the batteries to the consumption depends mainly on electronic devices that mediate between the battery and consumption.

For the installations that include AC consumptions (so an inverter is required) the electric losses of the inverter are taken into account, whereby σ_{BAT_MHE} = 0.90 - 0.92

Enter the power transfer coefficient (0 ... 1]:

Enter the aging coefficient of the battery system (0 ... 1]:

Enter the average annual temperature (°C) of the installation area of the accumulators:

The Nominal Capacity of the Batteries System that meets the power requirements are …... Ah

BATTERY's SPECIFICATIONS

Enter the nominal voltage [V] of the accumulator:

Enter the nominal capacity [Ah] of the accumulator:

Enter the weight [kg] of the accumulator:

Enter the length [mm] of the accumulator:

Type the width [mm] of the accumulator:

Enter the height [mm] of the accumulator:

Figure 8. Determination of batteries specifications.

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The next step requires the identification of electronic devices. In particular, if the power of the PV grid is less than or equal to 15kWp, a DC-AC voltage inverter is required whose characteristics need to be determined (Figure 9). On the other hand, when the field PV power is greater than 15kWp, a final voltage inverter is needed (Figure 10).

DC – AC Inverter
Enter continuous AC power [W] in 25oC:
Enter continuous AC power [W] in 45oC:
Enter continuous AC power [W] in 25oC for 30 minutes:
Enter continuous AC power [W] in 25oC for 1 minute:
Enter continuous AC power [W] in 25oC for 3 seconds:
Enter nominal AC current [A]:
Enter maximum output AC current [A] (duration: 500msec):

Figure 9. Entry DC – AC inverter features.

Therefore, Intermediate Inverter Voltages are used in conjunction with Final Voltage Inverters
Specifications of Final Voltage Inverter
Enter the nominal AC voltage [V] to the consumption of the final voltage inverter:
Enter the continuous AC power [W] at 25°C of the final voltage inverter:
Enter the continuous AC power [W] at 45°C of the final voltage inverter:
Enter the nominal AC current [A] of the final voltage inverter:
The battery system voltage [V] of the final inverter is set in the previous step and is equal to V_B
Enter the maximum charging current [A] of the battery system:
Type the current [A] of continuous charging the batteries at 25°C:
The Final Voltage Inverter selected is suitable in this designing

Figure 10. Entry intermediate inverter features.

The dimensioning and placement of PV modules is a critical issue. Typically, for determining the smallest incidence angle ε, the equation is chosen:

$$\varepsilon = 90^{o} - \delta - \varphi \quad (3)$$

where,

ε is the minimum allowable angle of incidence of the direct beam, G_{BEAM} at the installation place on 21st December (Northern Hemisphere)

δ is the solar deviation of that day (23.45°),

φ is the latitude (°) at the installation place

The equation (3) can ensure that during the midday of December 21st, all rows of PV modules will be fully covered by the direct beam over their entire surface, as shown in Figure 11. It is mentioned that the rest days of the year, the intensity of solar radiation is greater than one on the December 21st, so the calculated ε satisfies the minimum requirements.

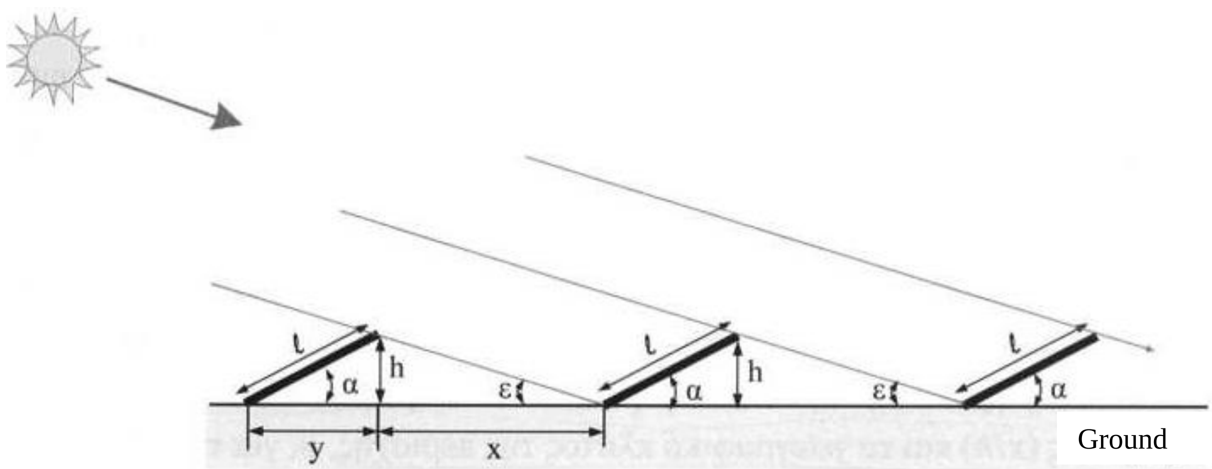


Figure 11. The geometry for the placement of consecutive PV modules of rows, on horizontal ground facing south.

Based on angle ε, the minimum acceptable distance (x + y) between two consecutive row frames can be determined from the relations:

$$h = l \cdot \sin(a) \quad (4a)$$

$$x = \frac{h}{\tan(\varepsilon)} = \frac{l \cdot \sin(a)}{\tan(\varepsilon)} \quad (4b)$$

$$y = l \cdot \cos(a) \tag{4c}$$

Thus,

$$(x + y) = \frac{l \cdot \sin(a)}{\tan(\varepsilon)} + l \cdot \cos(a) \tag{5}$$

Where,

h is the height due to PV module inclination

l is the length of PV module

a is the desired angle (in degrees) of the collectors

x is the distance between to PV modules in successive rows

ε is the minimum allowable angle of incidence of the direct beam, G_{BEAM} at the installation place (Northern Hemisphere)

y is the projection of PV module due to its angle, a

The equations (3), (4a-4c) and (5) provide an acceptable combination between the power provided by the side direct beam and the power delivered by the diffusive component on the day of the winter solstice. Also, possible economic and technical parameters determined by the ratio between the added benefit of the additional power output and the cost of the installation resulting from the higher surface binding (eg cost of larger cable cross-sections) are also taken into account.

In order to achieve the longest possible duration of solar energy in all rows of PV modules, it is necessary to determine the ratio of the x/h of Figure 11. Subsequently, the full coverage times of the immediate bundle of all frames are calculated, based on the size (x/h) and the latitude of the area, φ, for the worst day of the year (December 21st). This calculation is based on the solar geometry equations, using the following equations:

$$\omega = 15^o/h*(T_{SOLAR} - 12h) \tag{6}$$

where,

T_{SOLAR} the solar time for a particular are, the specific day in hours

ω is the solar hour angle

12 is the time for the solar midday (Sun at Zenith)

$15^o/h$ is proportionality constant between solar angle - hour and

$$\sin\beta = \sin\delta * \sin\varphi + \cos\delta * \cos\varphi * \cos\omega \quad (7)$$

where,

β is (the angle for) the height of the Sun in that particular place and time

δ is the solar deviation of that day of the year (DoY)

φ is the latitude of the location

ω is the hourly angle that corresponds to the time of calculating the position of the Sun.

Then, the x/h ratio is calculated based on the equation (4b)

$$x = \frac{h}{\tan(\varepsilon)} \Rightarrow \frac{x}{h} = \frac{1}{\tan(\varepsilon)} \quad (8)$$

where

ε is the minimum permissible angle of incidence of the direct beam G_{BEAM} at the installation location on December 21st (Northern Hemisphere)

x/h is the ratio between the spacing of two modules (x) in successive rows and the height (gradient) of the previous module, due to angle ε.

Depending on the full coverage hours, it is calculated the distance (x) between two consecutive PV modules rows and the x/h ratio, where x is the horizontal distance between two consecutive photovoltaic modules, and h the height formed by the slope of the PV module. Figure 12 shows the results.

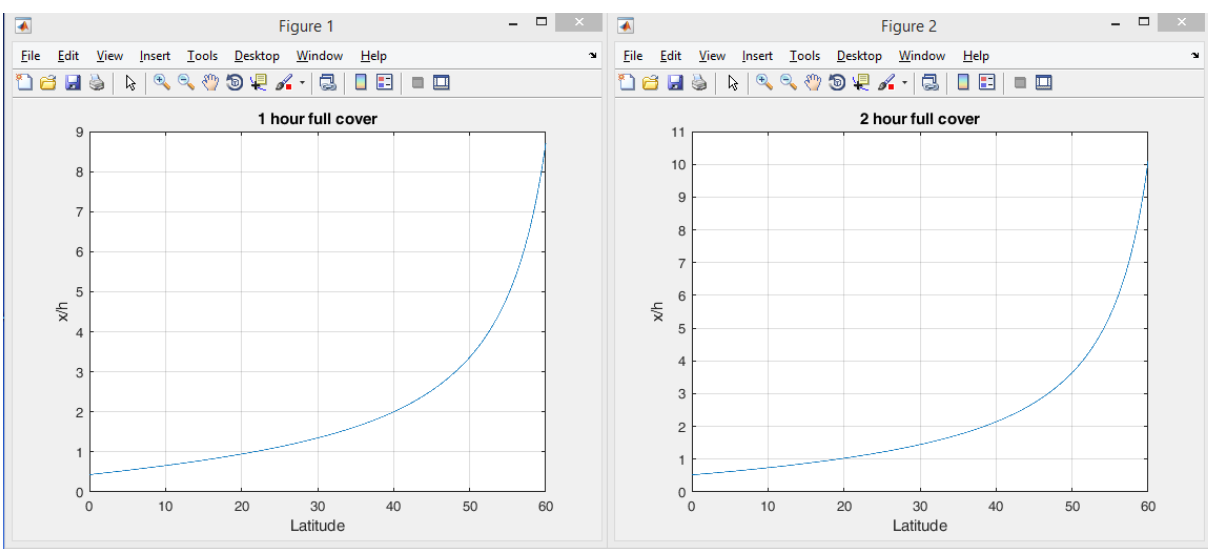
The required distance between two consecutive PV modules rows for 1 hour of full coverage is:…………

For the latitude region (φ) =

Hours of full coverage	ratio x/h	Distance of 2 consecutive PV module rows	PV module projection due to its inclination	Distance and projection between two PV modules rows
1 hour of full coverage	x/h =			
2 hours of full coverage	x/h =			
3 hours of full coverage	x/h =			
4 hours of full coverage	x/h =			
5 hours of full coverage	x/h =			
6 hours of full coverage	x/h =			
7 hours of full coverage	x/h =			
8 hours of full coverage	x/h =			

Figure 12. The results for distance (x), the x/h ratio and (x+y) distance.

The Figure 13 graphically shows the variation of the x/h ratio according to the latitude of the area for different full coverage hours.



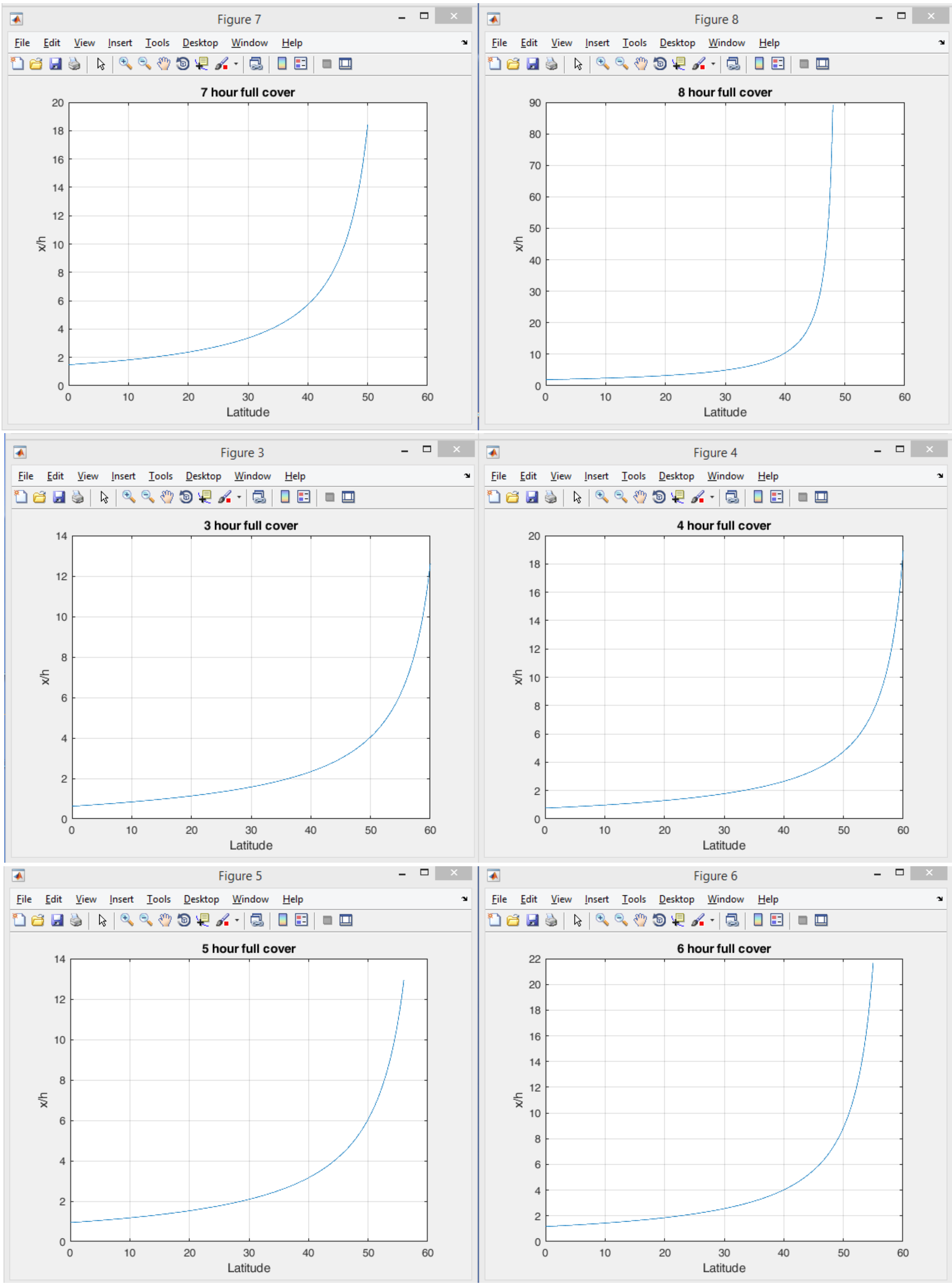
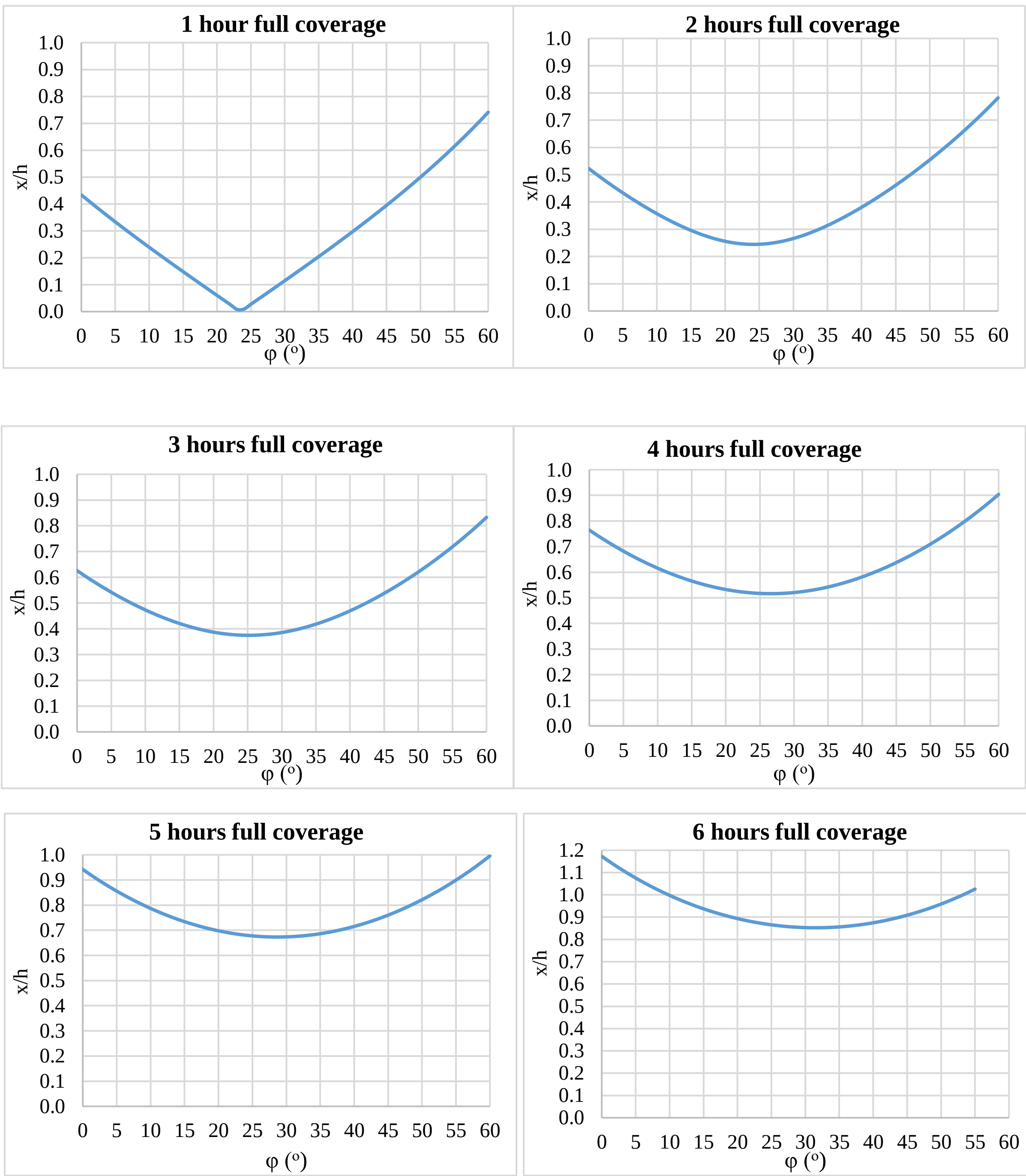


Figure 13. Graphical representation of variation of x/h ratio for different latitudes and different hours (1 to 8 hours) of full coverage.

The implemented software calculate and graphically display the ratio x/h in relation to the latitude (φ) of the installation area of PV grid for a different number of full coverage hours for any day of the year.

The Figure 14 depicts the variation of the x/h ratio according to the latitude of the area for different full coverage hours on June 21st.



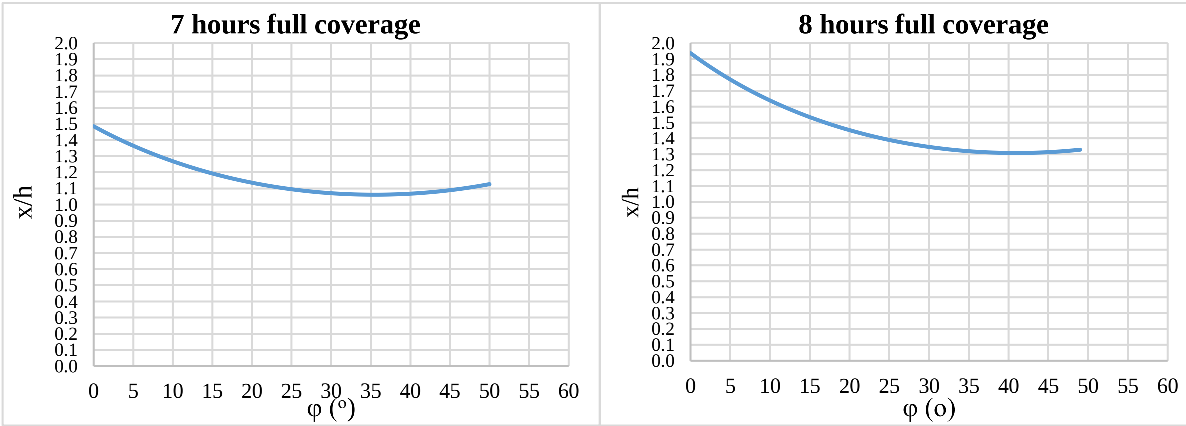


Figure 14. Graphical representation of variation of x/h ratio on the day of the summer solstice (June 21st) for different latitudes and different hours (1 to 8 hours) of full exposure to the direct solar beam of all PV arrays.

For completeness of the application, it has implemented a routine which calculates the cross sections of the cables between the different systems. This routine checks the total PV grid power and executes the appropriate code depending on whether this power is less than or equal to 15kWp or greater than 15kWp. This distinction is expected, as in the first case (≤15kWp) a voltage regulator and DC-AC voltage inverter are used, while in the other case (> 15kWp) intermediate and final inverters are required.

3. The implemented software

In this work, it was introduced a user-friendly and easy-to-use software for researchers, engineers and any interested user about the PV infrastructure design. Its important and innovative element is that it includes all the subsystems required in a study on the installation and use of PV modules. This application can be used for both autonomous and interconnected photovoltaic systems, based on user inputs. The dimensioning of a photovoltaic installation is of vital importance and the particular application places particular emphasis. This developed software includes a code for the calculation of the required batteries and the interconnection wiring of the various subsystems. This software incorporates intelligent algorithms to estimate solar power and power per day and for different latitudes. It is possible to calculate the solar energy at any point in a building installation knowing its geographical coordinates and altitude. The implemented software includes all the stages all the stages required for a photovoltaic (PV) installation is carried out. The technical features desired by the user are entered and there is no restriction on commercially standardized elements for both the photovoltaic panels and the inverters and the wiring of the installation.

This computational software contributes to the science of photovoltaic technologies as new photovoltaic elements with improved characteristics can be studied and developed, because it is possible to register in software of characteristic specifications beyond the standard commercial elements.

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