Architectural guide to calculate the area of solar cells in buildings (In Syria)

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Abstract:

Energy is the nerve of human evolution and is the cause of human conflicts and environmental pollution, thus renewable energy is the solution, and the sun is the most important sources.

The researcher has designed a program that calculates the initial space required by the solar cell system, according to the direction of the residential building.

To provide architectural conditions as (needed area, angel of system, cell quantities) that allow the designer to integrate the system with building design and thus achieve an architectural integration between the system and design.

The system will be part of the building as any other elements, without any need for engineering calculating for the system by the designer.

Key words: Energy- Renewable energy- Solar cell system - Architectural integration.

1- Introduction:

Energy is the cause of wars, and the availability of energy is the main factor of steadfastness, On the other hand, the development of societies and their economics and social progress depends on the availability of energy. Due to the energy crisis and the conditions that Syria is undergoing now, we are all driving our full scientific and cognitive capacity to seek ways to save energy cheaply, renewable and fast solutions. Accompanied by strategic solutions to this problem and hence emerged the idea of research.

Research on solar cells has evolved a lot but they lack the solar brightness, which we do not experience in Syria, so, how can we use solar energy through formations and new suburban residential structures for these buildings to be Self-sufficient electrical energy.

The process of designing the built-in solar cells system is determined by the available ceiling and facade area and the performance of the system is affected by the availability of solar energy, which must be guaranteed both at the time of system construction and in the future. Any structure or surrounding objects such as trees and other buildings should not shade the PV arrays at any time of the year, where shading reduces the efficiency of cells. The cells has to be choose with the yield proportionate with the energy consumption of the building to meet the maximum energy and thus accessibility Into a Zero energy building. However, this proce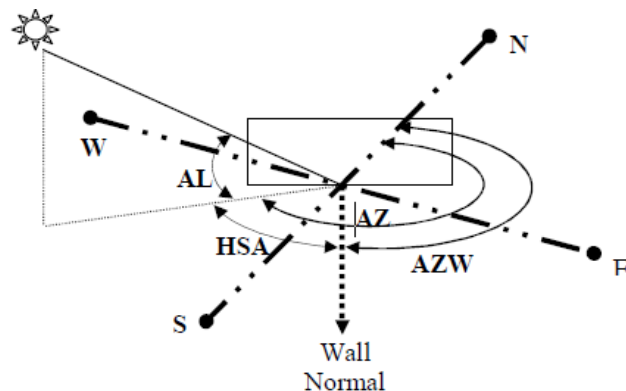ss needs research, analysis and calculation before the start of the design process and therefore it was necessary to collect the

Figure (1) solar coordinate system

information needed to calculate the area of cells and designing a program that does all the calculations necessary to facilitate the design process and is a working guide for architects before the start of the design process

2- Material and methods:

2-1- Calculating the solar radiation on the horizontal, vertical and diagonal surface:

- **Setting the location of the sun in the sky:**

The location of the sun is set in the sky at a specific time depending on the coordinate system as in Figure (1)

The location of the sun in the sky determined by two angles:

Angle of the sun height and is symbolized by AL (Altitude)

Which is the angle between the line of solar radiations and its project at the tangent level of the earth at that point.

Azimuth (AZ) is the angle between the line of the sun's rays on the earth and the north line clockwise, and its value is at north (0^0) and at the south (180^0).

These two angles to be calculate by the following formulas

$$Sin(AL)= Sin(LA) \; ' \; Sin(DE) + Cos(LA) \; ' \; Cos(DE) \; ' \; Cos(H)...$$

$$Cos(AZ) = \frac{Sin\,DE - Sin\,(LA)' \, Sin(AL\,)}{Cos\,(LA)' \; Cos\,(AL)}$$

Whereas:

: Latitude (LA) is the Latitude for the area

Declination (DE): The angle of the solar inclination, which is the angle between the sun's rays and the axis of the earth, and it is calculated by the following formula:

DE = 23 .45 * *Sin* (360 * (284 + *Don)* / 365).

Don: day of the year number.

Hour Angle (H): we get it by the following formula:

H = (15 **Time*) +180

Time is any hour of the selected day of the year (1- 24) putting in mind that the hour angle is determined by the regular rotation of the Earth around the axis and therefore is directly related to the time of the real sun.

- **Calculation of the Horizontal Shadow Angle (HSA)**

The angle between the sun's projection line on the ground and the vertical line on the wall at the angle of the horizontal shadow (HSA)

Rotate Angle (Ro): represents the rotation angle of the building to identify the direction of the building.

HSA= Ro - AZ

This angle is equal to zero when the width (WI) of the building is parallel to the north-south axis

In addition, the length (Li) of the building is parallel to the east-west axis (fig 2). The angle of shadow is calculate based on this.

I.e. when the building is directed to the north, the rotation angle is (Ro = 0) and the shadow angle is HSA = AZ

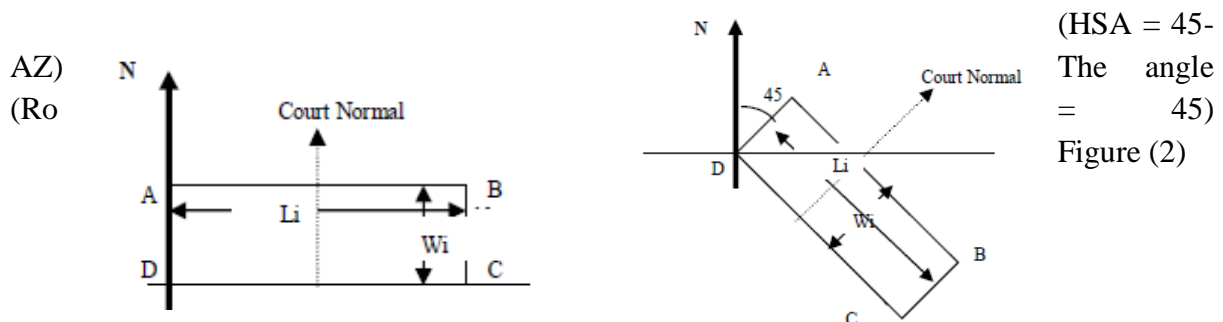When the building rotated at a certain angle (45) from the north

(HSA = 45- AZ) The angle = 45)

(Ro Figure (2)

Figure (2) simulation of the building orientation

- **Calculation of the intensity of direct solar radiation and radiation load:**

The simplest way to estimate the intensity of direct vertical radiation as a function of the elevation angle of the sun and assuming that the atmosphere is pure is as follows:

$$IDN = I \times \frac{0.921}{1 + \left[{0.3135}/{Sin\ (AL)} \right]}$$

Whereas: IDN. Direct vertical radiation intensity at a given time.

The solar constant is 1370

AL is the angle of sun's height at that time.

When we know the intensity of direct vertical radiation, we can calculate the radiation load on the horizontal surface

As measured by (Watt) of the following formula:

IDH = IDN´ Sin (AL) ´ A

Whereas: A is the surface area

To calculate the value of direct radiation on vertical surfaces, we use the following formula:

IDV= IDN ´Cos (HSA) ´Cos (AL) ´ A

A is the vertical surface area (the facade)

Distributed and diffused radiation from the surface of the earth (I_{TH})

$I_{TH} = C*I_{DN} + I_{DN}\ Sin\ (AL)$

Where c is a constant whose value given for each month of Table (1):

Table (1) C value during each month of the year

C	January	February	March	April	May	June	July	August	September	October	November	December
its value	0.058	0.060	0.071	0.097	0.121	0.134	0.135	0.122	0.092	0.073	0.063	0.057

In case, we have a tilted facade:

To calculate the radiation value on the tilted surfaces, we have to calculate the value of direct radiation and reflectivity on the slanted surface:

IDS= IDE+HD

IDS Radiation value on the tilted surface

IDE The value of direct radiation on the slant surface calculated from the formula

IDE= IDv\Sin β *A

IDv Radiation load on vertical surface

β The angle of the slope of the surface (the facade) from the horizontal surface and entered by the user

A is the tilted surface area

HD The value of reflected radiation on the tilted surface and is calculated from the formula

$HD=B*IDH*F_{SS}$

$F_{SS}=0.5(1+Sin\ β)$

B value calculated from Table (2) by month:

**Table (2) the value of the consonant B during the months of the year:**

Month	January	February	March	April	May	June	July	August	September	October	November	December
B ﺭ	0.142	0.144	0.156	0.18	0.196	0.205	0.207	0.201	0.177	0.16	0.149	0.142

Note: When we specify the angle of rotation for the building of the North, we can calculate the solar radiation on each façade, based on the its north orientation, and when the facade is inclined at a certain angle β; we can calculate the solar radiation on it.

2-2- Calculate the total consumption of the building by calculating the number of Flats and the area of each apartment

A statistical study to determine the consumption per square meter by taking many samples of flats of different areas and determining the consumption of each apartment and filtering the results through the statistical program spss. Figure (3)

Table (3) Area of flats, frequency and percentage:
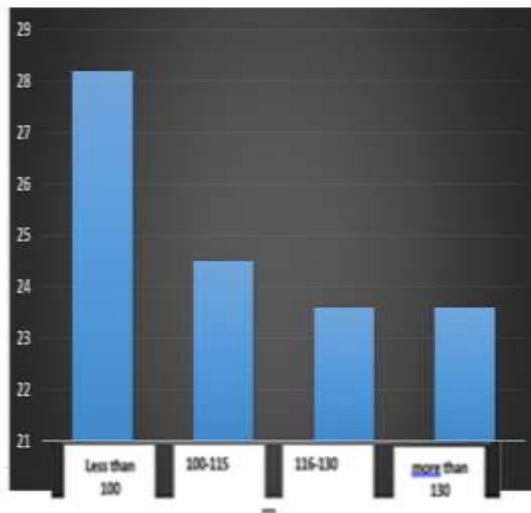
Apartment area	Frequency	percentage
Less than 100.	31	28.2
100-115.	27	24.5
116-130.	26	−23.6
More than 131	26	23.6
Total	110	100.0

Figure (3) Flat area and percentage

Table (4): Test the variance of the difference in consumption averages by area of the apartment

There were statistically significant differences between the average consumption of

	Number	Average	Standard deviation	Standard error	Minimum value	Max value	F values	Level of significance
Under 100.	31	1.412903	.1384243	.0248617	1.2000	1.5000	16.437	**0.000
100-115.	27	1.500000	0E-7	0E-7	1.5000	1.5000		
116-130.	26	1.534615	.0977438	.0191691	1.5000	1.8000		
More than 131	26	1.699000	.2645517	.0518829	1.5000	2.3000		
Total	110	1.530673	.1856263	.0176988	1.2000	2.3000		

residential flats according to the area of the apartment, where the value of F

16.437 and the value level of the significance of 0.000, which is a significant at the level of significance 0.01 Thus, we obtained the consumption of flats according to the area of square meters as in the following scheme. Figure (4)
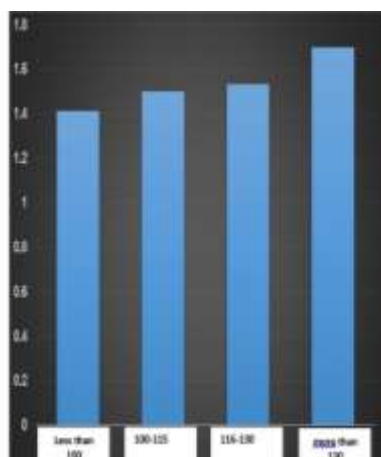

Figure (4) Consumption for flat area

2-3- Choosing cell type in terms of yield:

The architect selects the required type of cell based on a list of cells available in the local market and commensurate with the size and color with the design.

Table (5): Samples of solar cells available in the region

Weight mm	Dimensions mm			Current ampere	Volts	Capacity watts	Model
	L	W	H				
1.5	368	320	22	0.59	17.0	10	CNCB 10W
5.5	835	540	28	2.95	17.0	50	CNCB 50W
8.5	1210	540	30	5.56	18.0	100	CNCB 100W
12	1480	680	35	8.34	17.0	150	CNCB 150W
15	1580	808	35	5.26	37.5	200	CNCB 200W
23	1650	992	45	8.20	30.5	250	CNCB 250W
1.5	330	350	22	0.61	16.6	10	CNCC 10W
6	790	680	28	2.90	17.2	50	CNCC 50W
11	1192	680	35	5.78	17.1	100	CNCC 100W
12	1480	680	35	8.43	17.8	150	CNCC 150W
17	1480	992	35	7.63	26.2	200	CNCC 200W
18	1640	992	40	8.09	30.7	250	CNCC 250W

2-4- Calculating the number of cells on each facade:

Calculate the number of cells per facade according to the intensity of solar radiation: If they are less than 1000 watts, we do not distribute any cells on them, but if they are over 1000 watts, the number of cells distributed in equal proportions on the free facades

3- Results and Discussion:

As we determine the necessary steps to integrate solar cells in the building, it has to process by the program then entering the required data to obtain the desired results.

and thus the researcher designed a program that avoid the architect from performing long studies and gives accurate values of the need of the building energy and space to get the needed energy, and then comes the role of architecture and his/her creativity in designing the building to meet the required requirements.

3-1- Mechanism of starting the program:

When starting the program, the starting screen appears:

When pressing "Start a new project" ... The folowing screen pops up: fig. (5)

Figure (5) the program interface (1)

Then the latitude and longitude entered and move to the next step: Figure (6)
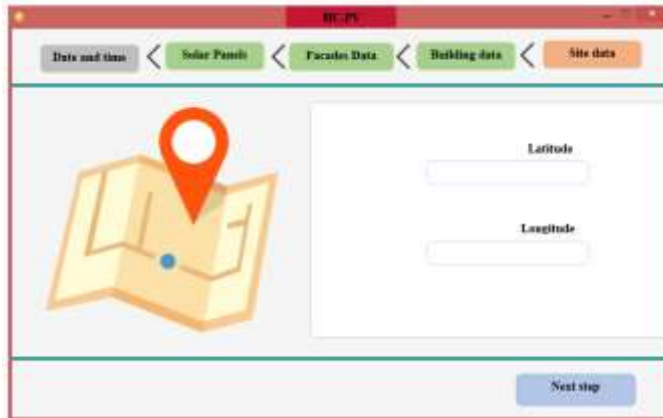
Figure (6) the program interface (2)

Entered the number of floors ...and the number of flats... The program automatically adds the numbers of the flats in the table...

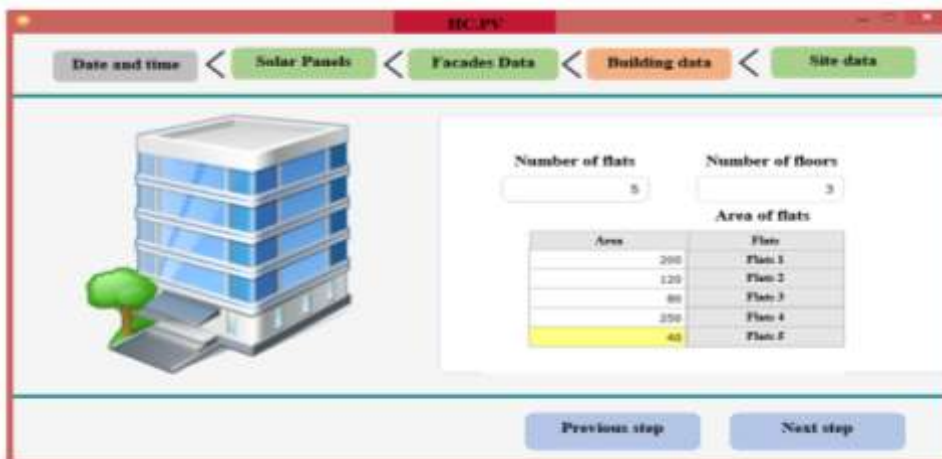Where the area of each apartment written in the table Figure (7)

Figure (7) the program interface (3)

And moves on to the next step:

Entering the facades information ... By default, we have four facades ... that can added to or deleted from them.

Data is entered ... For example, the first facades is called the "North Facades" and its data are entered (but the information is written without pressing any button) Figure (8)
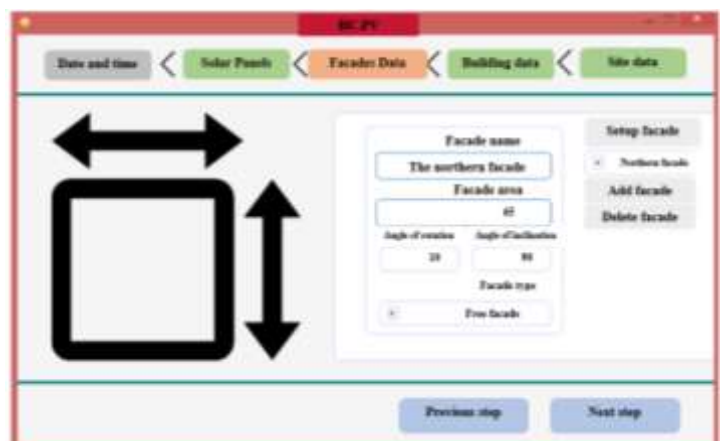

Then we move to the second facade...

Figure (8) the program interface (4)

And its information written such as "Eastern Facade"…. In addition, the steps repeated for all facades.

If there are more than four facades… The facade added by clicking on the button "Add Facade" and write its information.

When finished typing all information of facade we move to the next step:

Choosing a desired solar panel. We can add new panels or delete panels to the program via the buttons "add" and "delete". Figure (9)

Figure (9) the program interface (5)

Move to the next step:

Choose the day and time that will be the basis of calculation. In addition, click on OK.

Calculate and the facade shown in figure (10) will appear

On the right the project information … and on the left the calculation results.

Figure (10) the program interface (6)

As for project information: anything can changed by pressing the button "Edit" in any part: Figure (11)

Figure (11) the program interface (7)

As for "date and time" section. Any change in the calculation is the basis of the new date and time.

- For example if the timing at Sunrise when the radiation intensity is insufficient, the results shown in figure (12) appear.

Figure (12) the program interface (8)

We can change the panel and calculate results for a second panel: Figure (13)

Figure (13) the program interface (9)

In addition, we choose any second panel and calculation is based on it.

We can save the project to a file by clicking on the "Save Project" button and you can open it later.

The radiation analysis button pressed to show this screen: Figure (14)

by default the radiation chart on each facade will be by the chosen day. Color of each line from the color name of the facade at the bottom of the screen. When you move the mouse pointer over the chart the values for each facade appear by certain minutes.

The blueprint for a particular month or year can obtained by choosing the required and pressing, "Calculate results". Figure (15)
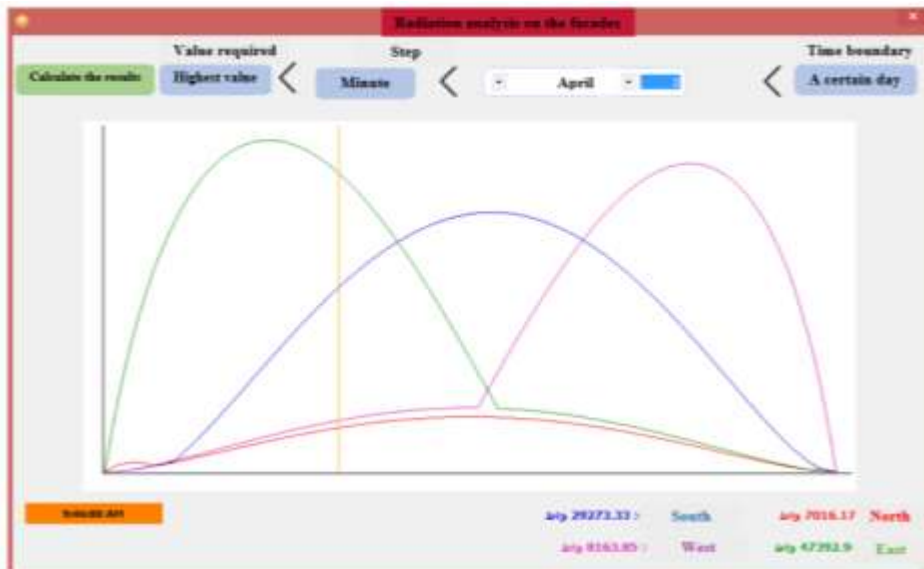

Figure (14) Simulation of the facade

Figure (15) simulate the facade with radiation values

4- Summary:

1- The program is usable and for all dimensions used in practical life.
2- The program user can conduct different case studies and select the best ones.
3- The results of the system are reliable in the architectural design of the buildings to choose the best.
4- Ease of manipulating the system by users who are not specialists by computers.
5- Simulation of the building provides the possibility of watching the solar distribution and the intensity of brightness on the building before the implementation of the construction, which saves a lot of effort, money and time.

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