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"Design and Installation Photovoltaic system in Car Parks in King Faisal University and Study the Economic and Environmental Impact"

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Abstract:

This study explores the direct relationship between sunlight and silicon photovoltaic cells that convert light into electrical energy. One of the most important applications that support reducing the dependence of educational facilities in university on the public grid of electrical energy is the exploitation of parking spaces which can support the generation of electrical energy of some MW's as clean renewable energy, which also supports sustainable development processes at the university level. This area constitutes an important part with the vision of the Kingdom 2030. The feasibility of using renewable energy alternatives is assessed after calculating the savings and payback. This design introduces a broader perspective to compare the alternative renewable energy systems in the car parking after estimating the total energy consumption in several buildings and infrastructures. This study also providing possible future production scenarios, considering the evaluation of the solar energy applications conducted for several years, in which the energy production system may change.

Keywords: National Renewable Energy Program (NREP,)Direct current Power Kilowatt (DC KW),Alternate Current Power Kilovolt Ampere (AC KVA),Direct current combiner (DCC) ,Alternate Current combiner(ACC),Photovoltaic array (PVA),Photovoltaic string (PVS) Solar Photovoltaic Energy (SPVE),Voltage Maximum Point (Vmp) Current Maximum Point (Imp), Electrical Grid company(EG)

"Design and Installation Photovoltaic system in Car Parks in **KING** Faisal University and Study the Economic and Environmental Impact"

Introduction:

The University City is equipped with all basic facilities for education, and in general consumes some hundreds of MWs because of its educational and service activity workloads, which necessitates paying the expenses of electricity bills annually. Installation and operation of the photovoltaic system on the campus, which in turn will provide part of the university's needs for electrical energy, thus reducing the value of the total electricity bill and reducing the amount of carbon emissions. Solar energy represents one of the natural resources of renewable energies that support sustainable development processes in the Kingdom Saudi Arabia. Rapid deployment of renewable energy and energy efficiency, and technological diversification of energy sources, would result in significant energy and economic benefits [Goswami, 2007]. Where the annual solar radiation rate in the Kingdom of Saudi Arabia (Al-Hassa) is about 2100-2200 kWh/m2 per year.

Scope of Research

The scope of research is to design, install, and operate of Photovoltaic system to provide Renewable energy with complete parts such as the solar Photovoltaic modules, the DC combiners, inverters, Ac combiners, and low voltage cables which in turn will provide AC power to the electrical panel of the buildings. Developing high-cost estimates and returns for energy alternatives compared to the electric current over 25 years by selecting facilities and estimating the total annual energy consumption

Main Objective

The research aims to develop an applied vision and **design** for the use of environmentally friendly SOLAR energy from sunlight in the parking spaces provided by the university to serve its students, faculty members and employees. So that it becomes one of the areas that support sustainability standards and become an element of economic, using the latest modern technologies of photovoltaic panels in maximizing the benefit of car umbrellas for these areas to become economically productive of electrical energy in addition to providing proper shading for cars **[Dalal, 1977].**

Secondary Objective

- Reduction of total cost of energy consumption.
- Choosing environmentally friendly energy systems
- Possibility to apply this **design** on similar projects in the campus under the same conditions in other words also the KFU Hospital project.
- Maintaining the environment by using the sustainability energy.
- Assessment of the efficiency of renewable energy systems considering the regional climate and environment.

- Decrease of electrical consumption by approaching to the new technology of renewable energy considering the climatic and topography criteria of campus project in the Eastern Region of Saudi Arabia (KFU) to get the least energy consumption.
- Utilization of modern alternative energy technologies
- Clarification of main implementation constrains of renewable energy and processing mechanism to keep efficiency.
- Comparison of technical and financial aspects of alternative energy based on engineering and environmental criteria.
- Recognition of new energy technology and possibility of implementing this study or adding the recommendations for the future.
- Providing feasibility of the study of using renewable energy systems infrastructures through the comparison between the life cycle cost of electrical power system and renewable energy for a period of years.

Methodology

The design in this research will take into account the applied descriptive approach and the features of developments in the production of clean renewable energy from sunlight at the level of the Kingdom of Saudi Arabia. It also focuses on the study of systems that can used based on environmental and climatic standards of the location. The most important of those elements are Photovoltaic Panels (PV) and Inverters [Lin, 2012].

I-Part one Design of Photovoltaic System

1. Parking Locations at the General Site of University

Figure1 depicts the plan of the main car parks of the university with a total area of thousands m2, where some designs have been developed for the car parking coverage by PV Modules, primarily based on the longer life of the materials used in addition, the cost available. Figure (2) depicts the selected useable parking zones for solar PV modules installation system for this research (Table 1).

Figure (1)

Parking Locations at the General Site of University

Figure (2)

Useable Parking zones for solar PV installation system

Table (1)
Parking zones with cars number

LOCATION	ZONE	NUMBER OF CARS
ADMINISTRATION BLDG	A	50
DINNING HALL	B	92
MOSQUE	C	181
COLLEGE OF SCIENCE	G	78
COLLEGE OF BUSINESS BOYS	K	120

2. Photovoltaic System Components

The photovoltaic system consists mainly of solar panels and solar inverters in addition to electrical panels for DC combiner, alternating current, protection, control and monitoring devices. Adding to infrastructure for cable sets for alternating and continuous voltage and power meters. Where, it supplied and installed from reliable and leading local companies in this field. For aiding the design and the research, the technical specifications of each element with the latest appropriate technology and at a low cost, will display, select and explain as follows:

2.1-Monocrystalline PV Module

The most important element of the solar system where the sun light transfer to electrical current is PV modules [Prudhui, 2012]. Figure (3) illustrates the three types are available in the market. It is important to study and simulate the solar system to the connection point of electrical panels, but it is not forbidden to choose the best in the market (Figure 4) (BISOL 2000mmx1000mm approximately) Monocrystalline type and the specification (Table 2) and install them in all parking zones. Which is in turn considered the First important stage of this design.

Figure (3)
Three main Solar Panel Types
Figure (4) **BISOL**

Photovoltaic Module

Table (2)
Bisol Technical specifications

BISOL d.o. o	
Rated Power	**310W**
I short circuit	**8.85A**
V open circuit	**46.6Vdc**
RATED Max CURRENT	**8.4A**
Rated Max Voltage	**36.9V**

Knowing the voltage of the open circuit for each panel (46.6v) (Table 2), the number of modules for each string can calculated, and where these modules connected at series, the voltage must not exceed 1000 volts DC per string. Figure 5 depicts these PV Panels Installation for Some Zones A and zone B. Where the dimensions of each module are (2mx1m). Testing and inspections done to insure the correct connection for the next stage.

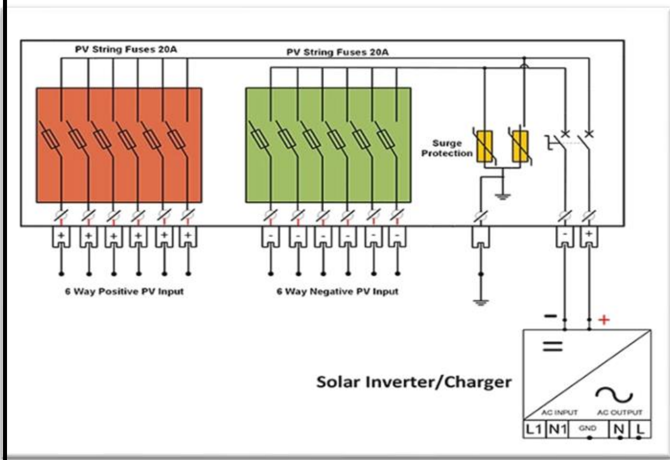
Figure (5)
PV Panels Installation for Some Zones A and zone B
.

2.-2 DC Combiner:

DC combiner is a DC electrical protection panel with a main breaker designed for a value, 63 A depend on the number of connected strings. Each string connected to double pole circuit breaker negative and positive terminals (for example one Array four strings 16A each). In this research the locations and numbers of DC combiner for two types with fuses or CB, (Figure 6) will determined in stage three.

Figure (6)

DC Combiner with Fuses and CB



2.3 Solar Inverter:

It is a solar power electronic transformer, which transfer the DC input power connected from DC combiner with calculated parameters of voltages, currents, and power KW to three phases AC power output KVA. Each solar inverter has deferent specifications regarding to the manufacture companies, which cover our need with good quality and efficiency such as some companies' (SMA2000TL, HUAWEI SUN2000, and FRONUS). Because of the comparison between the technical specifications (Kw, Kva, IDC, IAC) of the inverter manufacturers, (FRONIUS) was chosen which has the best specifications and approved from EG Company and will connected to the electrical panels of the buildings (Figure 7). Figure 8 depicts the data sheet and installed FRONUS inverter.

Figure (7)

Technical Specifications Comparison between Manufacture Companies of Inverters

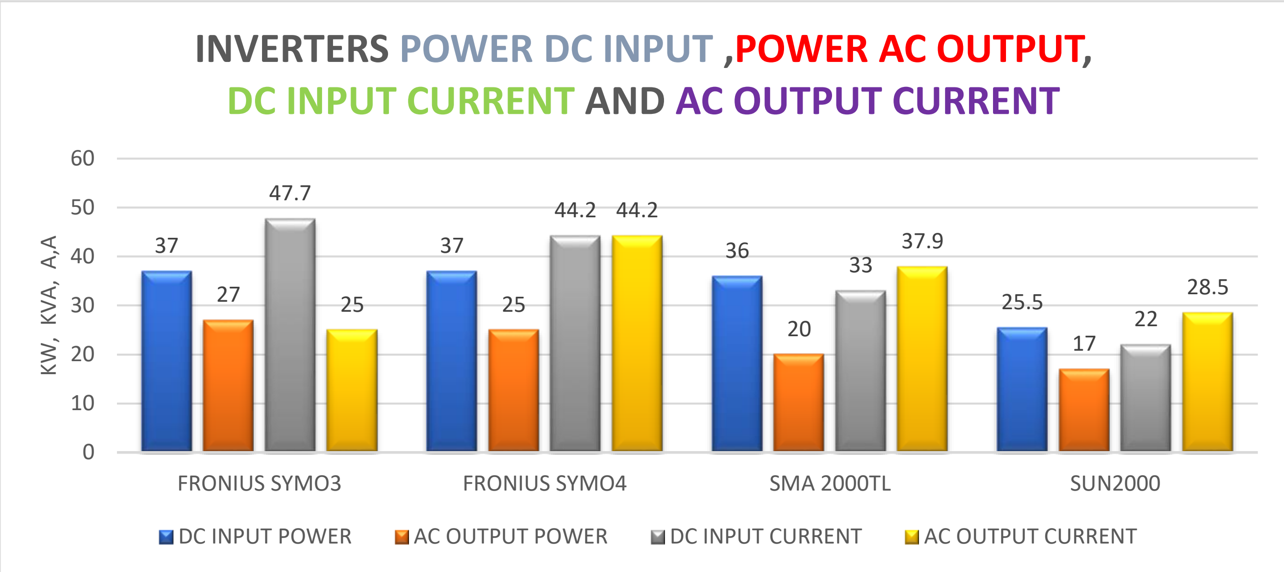


Figure (8)

Data Sheet and Instilled FRONIUS Invertor

The most important parameters are the Dc Input KW (37) Kw, the AC power output (25, 27) KVA, Max voltage input (1000 V), Grid connection ($U_{ac,r}$ 3 NPE 400/230V), and AC

output Current ($I_{ac\ nom}$). In this design third stage, the locations and numbers of solar inverters will also determine for each parking zones.

2.4-AC Combiner

It is an electrical protection panel which is part of the AC network of the solar system to connect number of Inverters with three phase low voltage cables (1000v) (4c x16mm2 XLPE/CU/PVC +E) as designed number of arrays, each inverter with three phases CB (63A). Then the AC Combiner with main CB 200A is connected by low voltage cable as designed, to the nearby appropriate buildings electrical panel through power meter (Figure 9). In this research as part of stage two the locations and numbers of solar AC combiners will determine.

Figure (9)

Three phases AC Combiners installed with number of CBs and Fronus Smart meter [14]

2.5-Software and Accessory:

To complete the research and the design from solar power generation to the delivery of alternating current to the appropriate buildings through combiner's panels. First, must use the simulation available programs such as (PVSYST, Helioscope, or www.photovoltic-software.com) [Appendix A] to calculate the energy generated KWh/year, the DC power, and the AC power. Information is needed for input data such as project summary (Geographical Site), System summary (Grid connected PV field orientation, Tilt/Azimuth) and system information (PV array number of modules, inverter rating, and location). Therefore, result summary output of the simulation can used to program the inverter to suit the obstacles are recorded and monitoring for all elements of the system. Second, the entire system must ground from the solar panels to all solar system. Third, installation of high-voltage protection elements (SPD) for each AC Combiner panel.

2.6-Infrastructure Duct Bank and Cabling:

The second stage of the research after confirming the completion of the installation of all PV solar modules is the design and analysis to determine the locations of solar inverters and DC combiners. So, Infrastructure works require the installing the designed distribution DC cables to connect modules with DC combiner by PV solar cable (2x4mm2) and then by PV cable (2x6mm2) to the inverters. Then, designing and determine the sizes and connections of AC cables from solar inverters with AC combiner, also through Manholes and duct bank with suitable pipes according to the number of cables, to the nearby appropriate buildings after knowing the loads of current and capacity. This stage has been success fully tested and examined to implement the third phase.

3-Design, Study, and Analysis of Some Repetitive Models in Parking Lots

The panels are connected according to the number of strings and arrays with the DC combiner and then to the inverter, from which calculate the current, voltage and power using the technical specifications of software and the PV panels. The open circuit voltage of each string must not exceed 1000 V as invertor requirememts.

3.1- Model number one using 1 Array with 4 Strings each with 20 PV panels in series:

The Input DC power= 24.8 Kw and the Output AC power = 20 KVA as illustrated in Figure (10).

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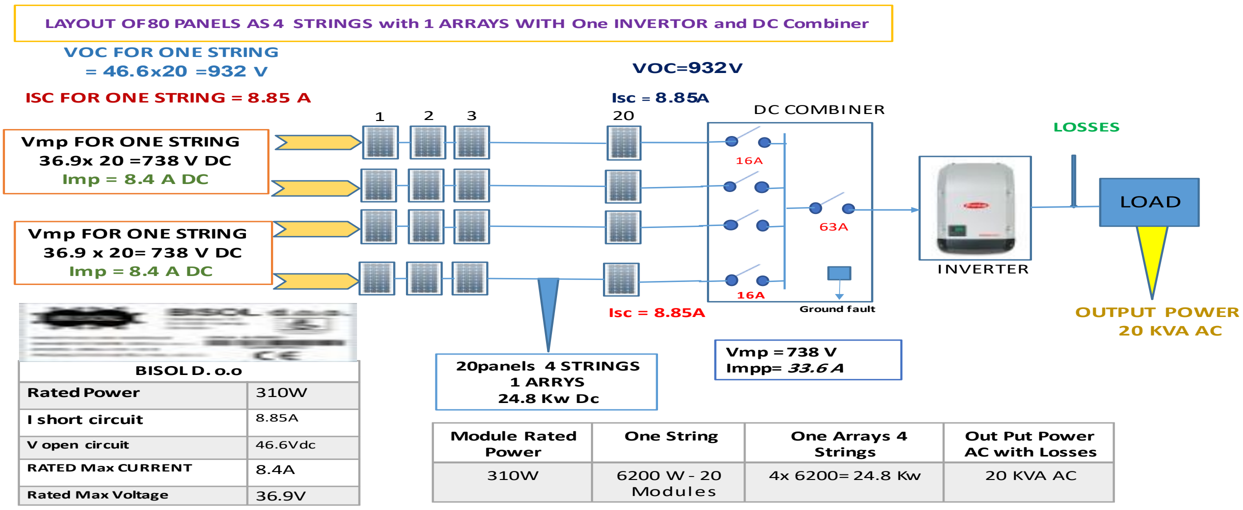
Figure (10)

Model One 4 Strings 20 Modules in Series Each power 24.8 kW DC

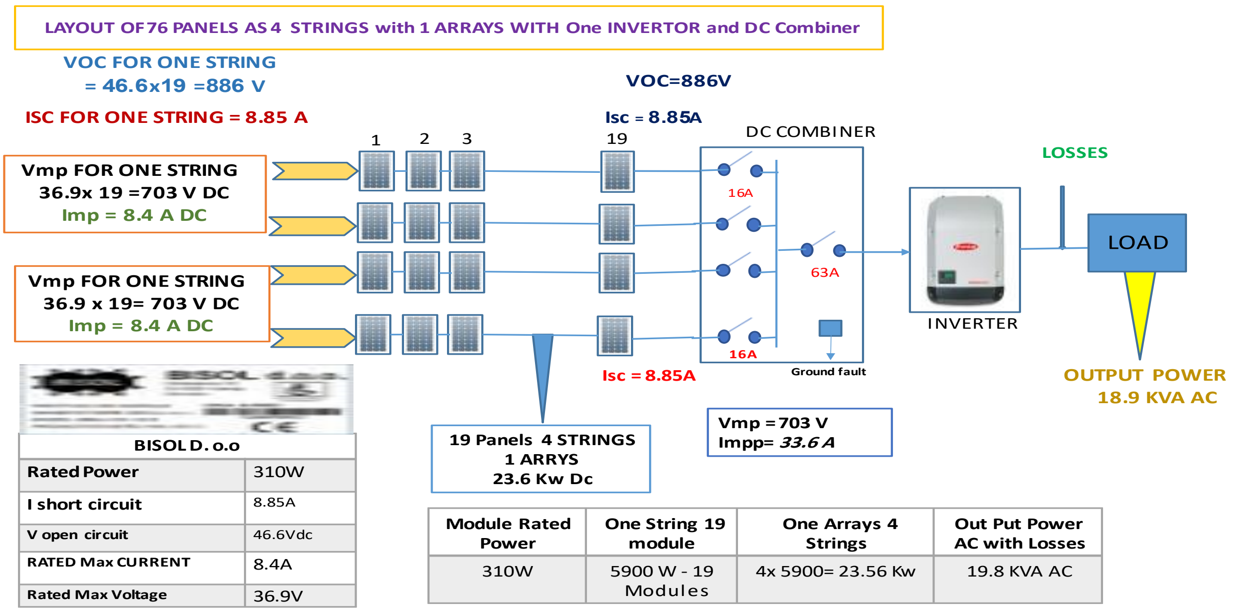


3.2-Model number two using 1 Array with 4 Strings each with 19 PV panels in Series:

The Input DC power=23.6 Kw and the Output AC power=18.9 KVA as shown in Figure (11) the same result as Appindex (A) PVSYST simulation report.

Figure (11)

Model Two 4 Strings 19 Modules in Series Each Power 23.6 KW DC



3.3-Model number Three using 1 Array with 3 Strings each with 20 PV panels in series:

The Input DC power = 18.6 Kw and the Output AC power = 14.88 KVA. As Appendix (C) PVSYST simulation report.

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3.4-Model number Four using 1 Array with 3 Strings each with 19 PV panels in series

The Input DC power = 17.7 Kw and the Output AC power = 14.17 KVA.

II-Part Two Installation in parking Lots

Practical analysis must be done in order to install the solar system elements of parking zones, such as the solar inverters, DC combiner. By using simulation will make sure all data are correct, therefore programing the inverters for third stage of the research. Then the most practical Power meters must install to measure the right value of produced AC power for each Ac cable connected to the electrical panel of the buildings

1. Parking Section A

To design and determine the number of solar equipments, the number of solar panels installed that took place in previous stages must be determined (Table 3) . Fhgure 12 illustrae the calculating number of PV panels used (each car 6 PV panels), can connected according to the requirements and design limits) for zone A.

1.1-Design Mechanism

Figure (12)

Parking zones A

Table (3)

Table (3) Solar Panels and cars Numbers

Parking Zone	Umbrellas of Cars	Solar Panels Installed
A1	13	78
A2	10	44
A3	10	44
A4	11	66
A5	6	36
TOTAL	50	268

The design mechanism depends on determining the number of solar models that connected in each zone. Then calculating the DC power input connected for each DC combiner. Figure 13 depicts an example of (PV) panels schematic diagrams for parking zone A1 and in practice we have 19 modules in series for one string produced 5.89 KW DC (Figure 11).

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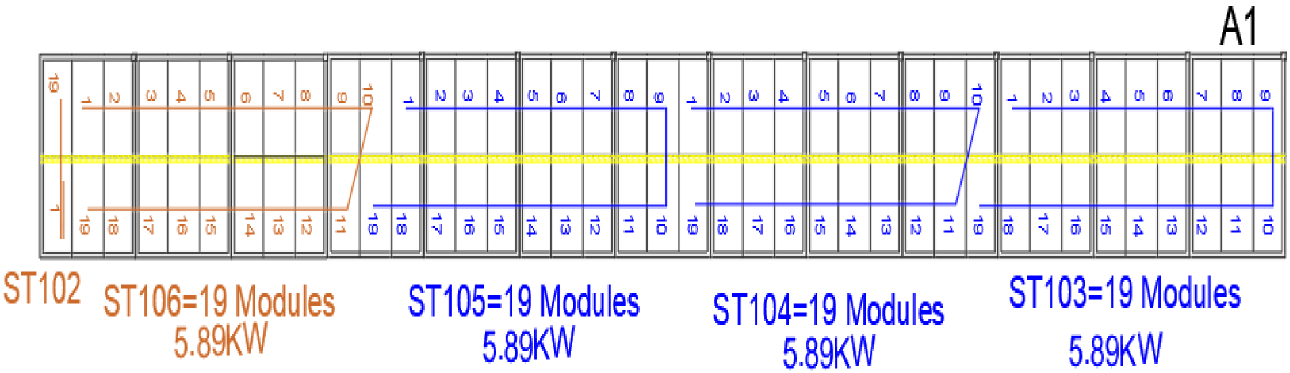
Figure (13) PV Panels Schematic Diagrams for Parking A1 and Practical Design and Connections



Therefore, by schematic diagrams for all photovoltaics components systems of parking A, the total number of the inverters, DC combiner, AC combiner, and the value of produce DC power can determine which equal to 83.2 KW DC, the output Power AC equal to 66.5 KVA include Performance ratio and losses coefficient where losses details (depend on site, technology, and sizing of the system) equal to 0.79, (Table 4). To finish the analysis and the solution by knowing the produce AC power is to calculate the current and the AC cable size to the building that is 4 x 70 mm2+35 mm2.

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Figure (14)

Schematic Diagrams for all Photovoltaics Components System of Parking A

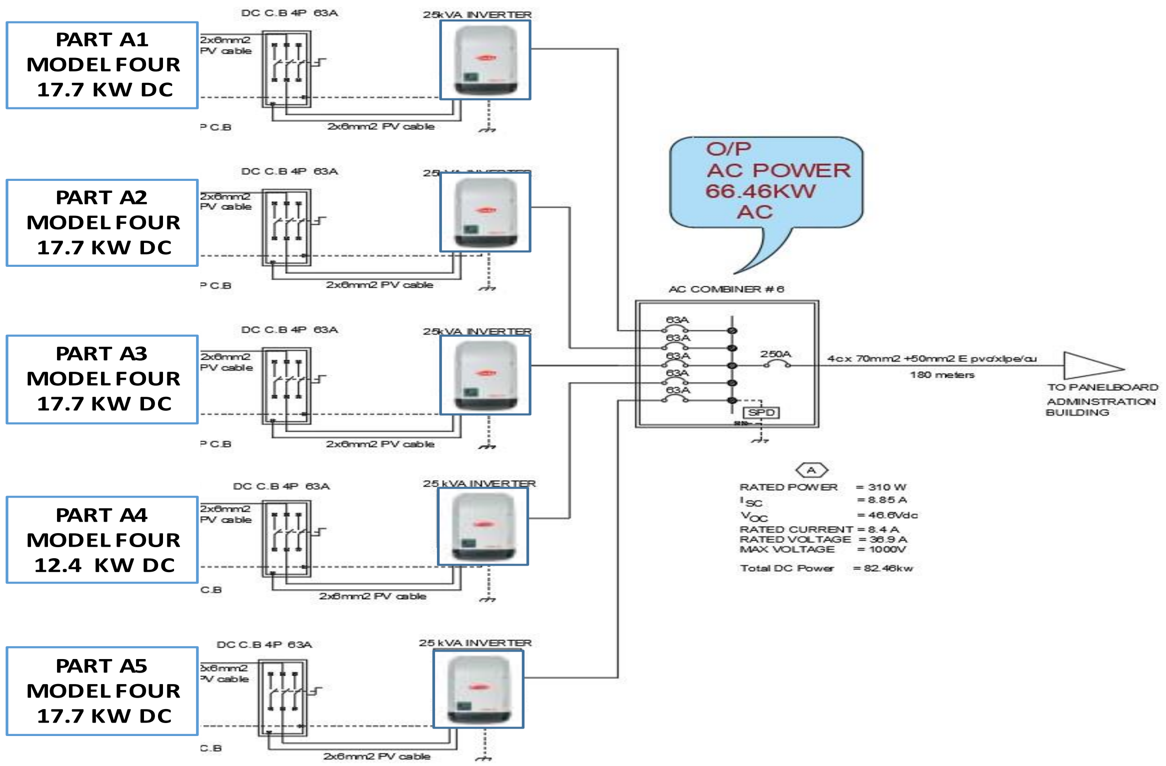

Table (4)
losses details

System details	Losses
Inverter losses (6% to 15 %)	6%
Temperature losses (5% to 15%)	7%
DC cables losses (1 to 3 %)	1%
AC cables losses (1 to 3 %)	1%
Shadings 0 % to 40% (depends of site)	3%
Losses weak irradiation 3% to 7%	3%
Losses due to dust, snow... (2%)	2%
Performance ratio, coefficient for losses	0.79

The final step for Design Mechanism is to confirm the correctness of calculation of the solar PV energy 137,837 KWh/year and AC Power output 66 KVA of a photovoltaic system for parking (A). Figure 15 illustrates a simulation program using (Solar PV energy output software).

ISSN: 2663-5798

Figure (15)
Calculation of The Solar PV Energy and AC Power Output of a Photovoltaic system(A)
2. Parking Section B

Calculation of the solar PV energy ouput of a photovoltaic system

(yellow)	Yelow cell = enter your own data
(green)	Green cell = result (do not change the value)
(white)	White cell = calculated value (do not change the value)

Global formula : E = A * r * H * PR

E = Energy (kWh)	137,837	kWh/an
A = Total solar panel Area (m²)	536	m²
r = solar panel yield (%)	16%	
H = Annual average irradiation on tilted panels (shadings not included)*	2100	kWh/m².an
PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75)	0.79	
Total power of the system	83.08	kWp

Losses details (depend of site, technology, and sizing of the system)

- Inverter losses (6% to 15 %)	6%
- Température losses (5% to 15%)	7%
- DC cables losses (1 to 3 %)	1%
- AC cables losses (1 to 3 %)	1%
- Shadings 0 % to 40% (depends of site)	3%
- Losses weak irradiation 3% yo 7%	3%
- Losses due to dust, snow... (2%)	2%
- Other Losses	0%
S = Total System Power Output from AC Combiner	66 KVA

Zone (B) is divided into six zones with parking for 92 cars (B1 – B2 – B3 – B4 – B5 – B6) as Table 5 and Figure 16.

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ISSN: 2663-5798
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2.1-Design Mechanism:

The same design mechanism in Parking (A) for determining the number of solar models that connected in each array is used. Figure 17 illustrates Single Line Diagram of all solar system components designed for the parking B. Then a program

Figure (16)
Parking zones B

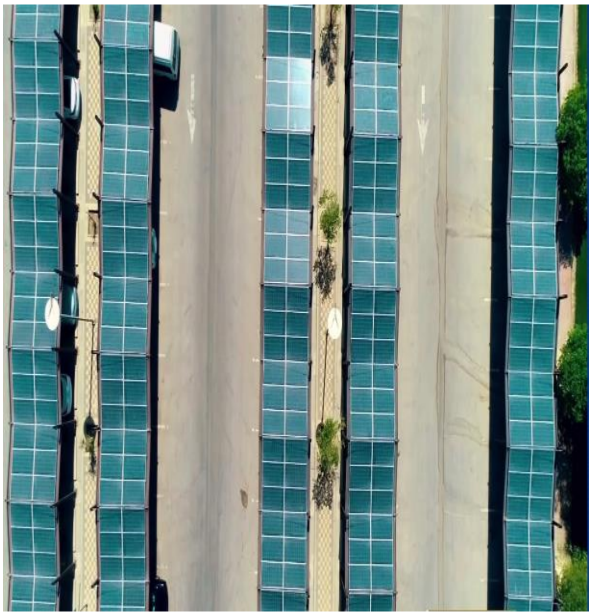

Table (5)
Solar Panels and cars Numbers Zones B

Parking Zone	Umbrellas of Cars	Solar Panels Installed
B1	11	66
B2	7	42
B3	16	96
B4	16	96
B5	21	126
B6	21	126
TOTAL	92	552

using (Solar PV energy output software) as shown in Figure (18) solar PV energy and AC power output can calculated which equal to 167.8 DC KW, the output Power AC is equal to 134.3 KVA.

ISSN: 2663-5798

Figure (17)

Single Line Diagram of all solar system components designed for the parking B.

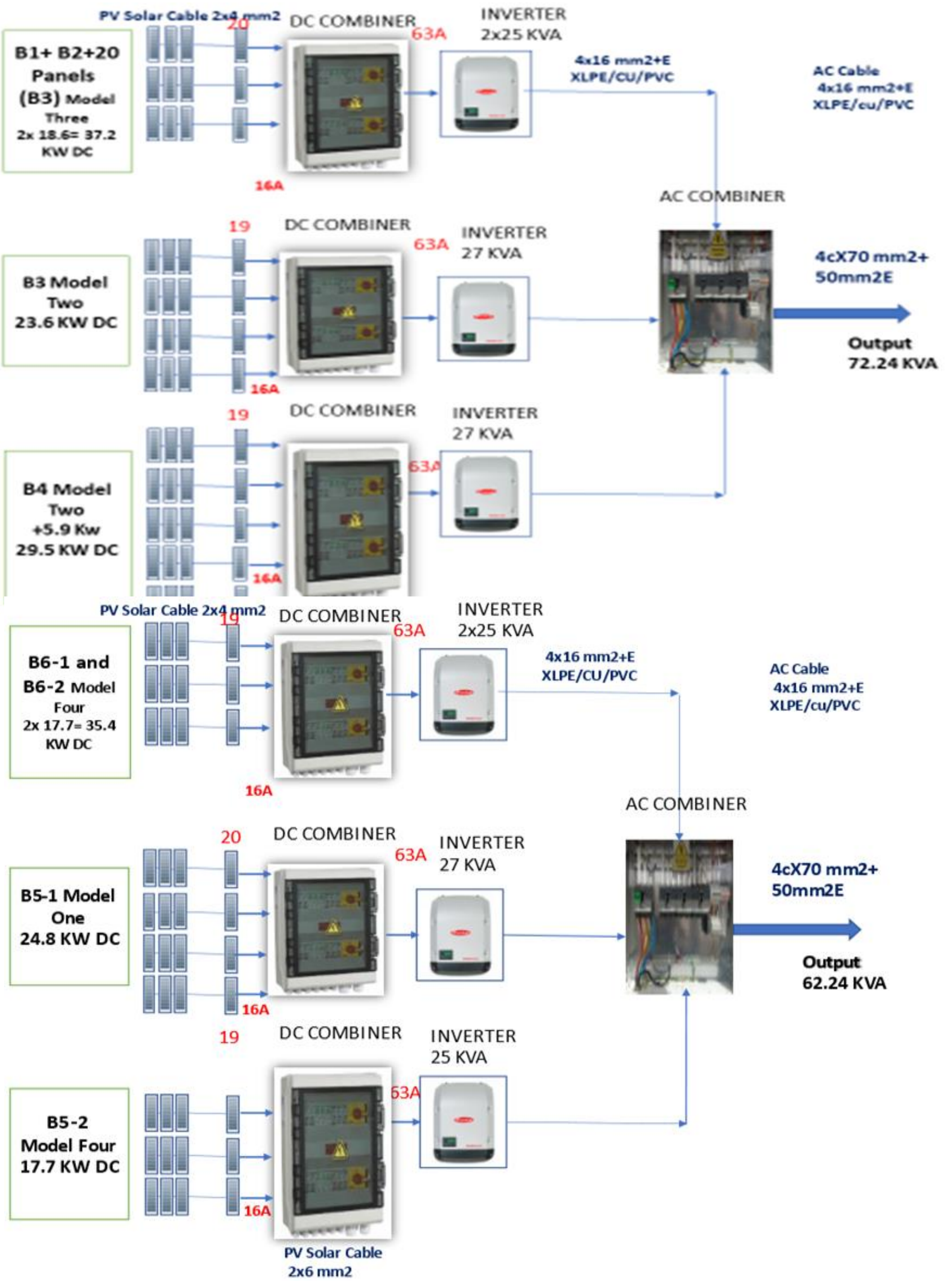

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Figure (18)
Solar PV energy output Software for parking (B)

3. Parking Section C

Calculation of the solar PV energy ouput of a photovoltaic system

(yellow)	Yelow cell = enter your own data
(green)	Green cell = result (do not change the value)
(white)	White cell = calculated value (do not change the value)

Global formula : **E = A * r * H * PR**

E = Energy (kWh)	278246	kWh/an
A = Total solar panel Area (m²)	1082	m²
r = solar panel yield (%)	16%	
H = Annual average irradiation on tilted panels (shadings not included)*	2100	kWh/m².an
PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75)	0.79	

Total power of the system 167.71 kWp

Losses details (depend of site, technology, and sizing of the system)

- Inverter losses (6% to 15 %)	6%
- Température losses (5% to 15%)	7%
- DC cables losses (1 to 3 %)	1%
- AC cables losses (1 to 3 %)	1%
- Shadings 0 % to 40% (depends of site)	3%
- Losses weak irradiation 3% yo 7%	3%
- Losses due to dust, snow... (2%)	2%
- Other Losses	0%

S = Total System Power Output from AC Combiner	132	KVA

Parking (C) is divided into seven zones with parking for 181 cars (C1 – C2 – C3 – C4 – C5 – C6 – C7). The total value of produce DC power can determine which equal to 332.4 DC KW and output Power AC is equal to 263 KVA.

4. Parking Section G

Zone (G) is divided into four zones with parking for 78 cars (G1 – G2 –G3 – G4) Figure 19. The total value of produce DC power determined which equal to 144.3 DC KW and output Power AC is equal to 115.4 KVA (Appendix C).

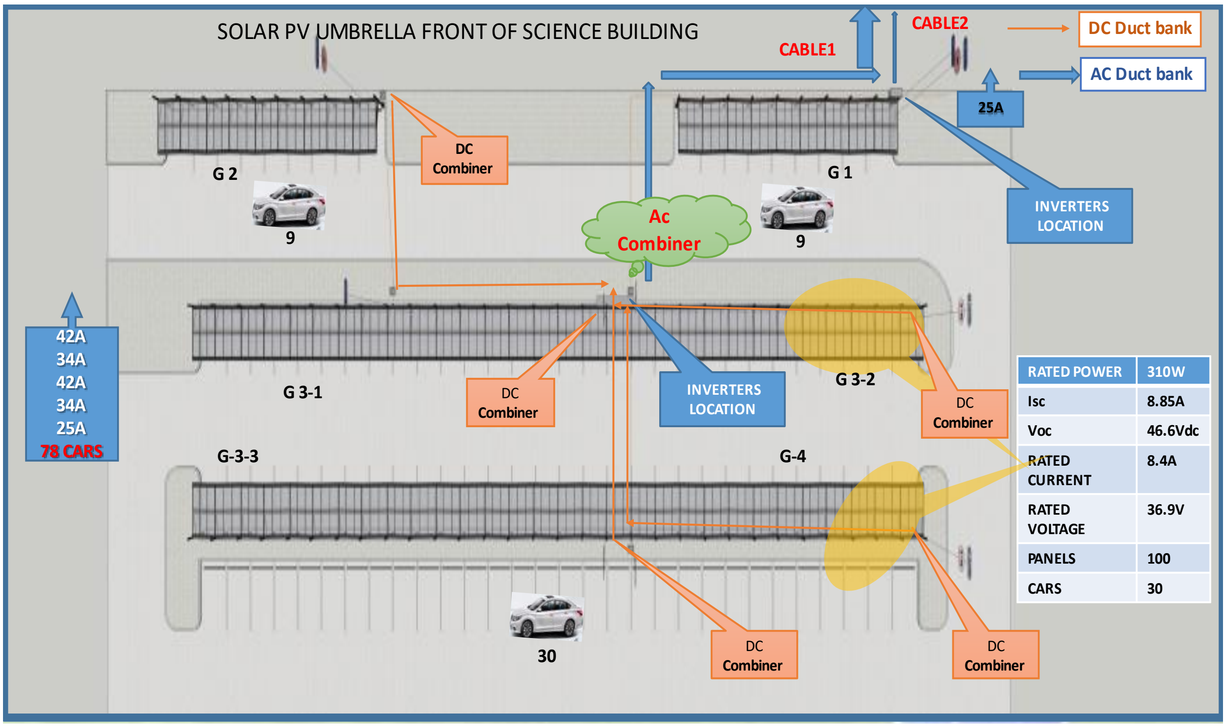
5. Parking Section G

Zone (K) is divided into ten zones with parking for 120 cars and the produce DC power is 217 DC KW the output Power AC is equal to 173.4 KVA.

ISSN: 2663-5798

Figure (19)
Parking Zones G Schematic Diagrams for all Photovoltaics Components Systems

III-PART THREE The Financial Study and Resulting Savings



Finally, the most important step in this research is to calculate the financial study and desired result of savings after installing of appropriate solar system elements especially more than **three thousand solar modules**, the INVERTERS and AC Combiners for all parking zones A, B, C, G, and K as was done in PART ONE of this research.

1. **Initial Costs**

In order to analyses the Cumulative Revenues cost and calculating the saving result, the initial cost through this research must be determined for three sections. The first section is the fixed cost of photovoltaic panels (3050) at a value of 1,400,000 riyals. The second section is the cost of infrastructure for the duct bank trenches, alternating voltage cables with extension and installation, and alternating current combiner panels at a value of 1,090,000 riyals. The third section is the cost of Inverters (electronic Transformers), PV DC cables, and protection panels for DC combiner with total cost of 880,000 riyals. The total cost of all sections will be 3,370,000 SAR as average 3,500SAR / KW DC power generated. Table (6) shows the generation of electrical energy from the PV solar and the AC power connected to each building where power meters will connect to measure the AC Power generated.

LOCATION	DC Power Kw	AC Power KVA	Electrical Energy Generation KWh/YEAR
PARKING A	83.2	66.5	137,837
PARKING B	167.8	134.3	278,246
PARKING C	332.4	263	551,349
PARKING G	144.3	115.4	240,187
PARKING K	217	173.5	366,194
TOTAL	945	753	1,573,813

Table (6)
Total generated Solar PV Energy output of a photovoltaic system and AC Power

2. Continuous Costs

The maintenance cost is approximately in one year 10 thousand riyals and over a period of 25 year adding 5 thousand each year. As for the life span of the solar system, it is as follows: Solar panels (25) years and Inverter (25 years). There is no cost for spare parts.

3. Cumulative Revenues (SAR) Parking

Cumulative revenues analysis can determine using the results of the system price, operation and maintenance price, and the saving amount of 520 thousand SAR in the annual consumption of electricity, over a 25-year period in one table (Table 7). Figure 20 illustrate the cumulative revenues and payback study resulting using data (Table 7) on charting as Y-axis (for 25 year) and X -axis (for cumulative revenues) [Boer, 1978].

Table (7)

System cost, the value of savings for electricity consumption and the period of repayment

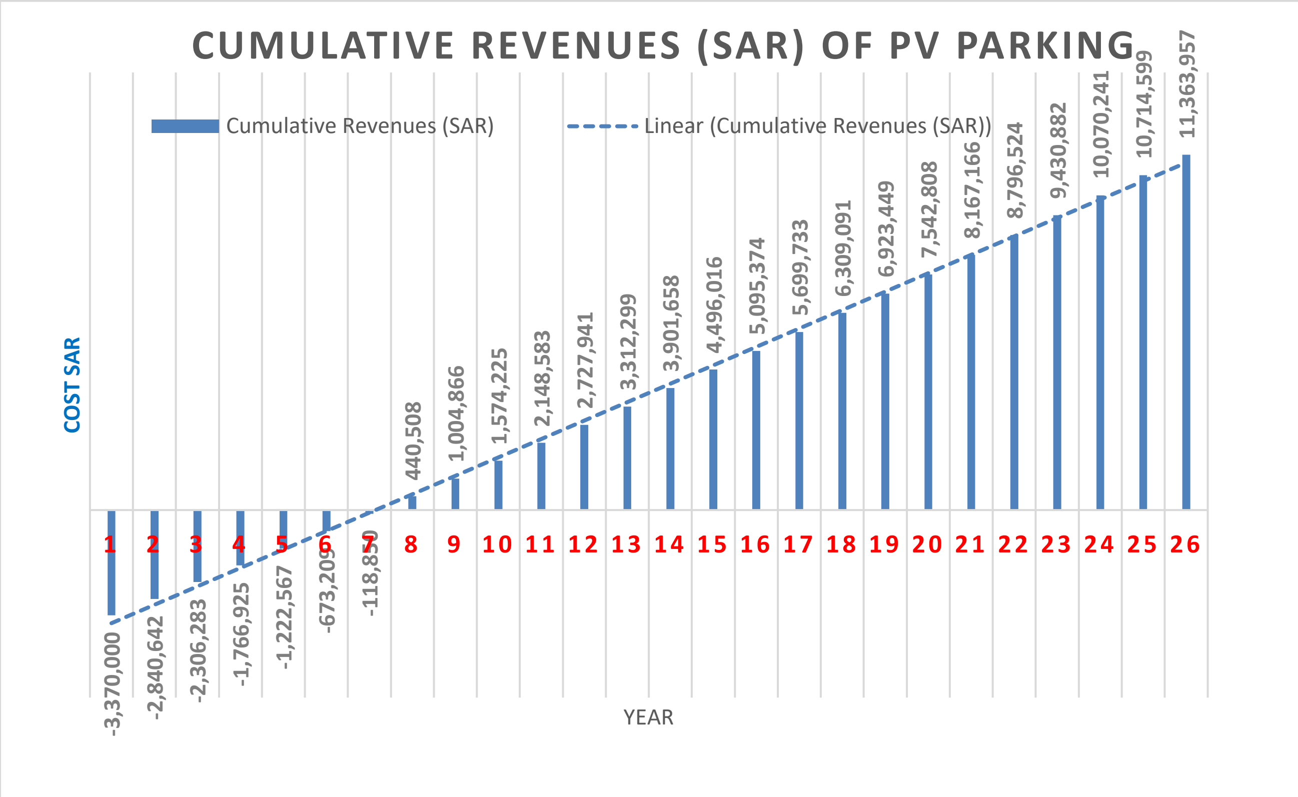
Year	System Price (SAR)	ENERGY KWh/year	Saving	Maintenance Normal Cost	Savings (SAR)	Cumulative Revenues (SAR)
0	3,370,000	0		10,000	0	-3,370,000
1	3,370,000	1,573,813		10,000	519,358	-2,840,642
2	3,370,000	1,573,813		15,000	519,358	-2,306,283
3	3,370,000	1,573,813		20,000	519,358	-1,766,925
4	3,370,000	1,573,813		25,000	519,358	-1,222,567
5	3,370,000	1,573,813		30,000	519,358	-673,209
6	3,370,000	1,573,813		35,000	519,358	-118,850

ISSN: 2663-5798

7	3,370,000	1,573,813	40,000	519,358	440,508
8	3,370,000	1,573,813	45,000	519,358	1,004,866
9	3,370,000	1,573,813	50,000	519,358	1,574,225
10	3,370,000	1,573,813	55,000	519,358	2,148,583
11	3,370,000	1,573,813	60,000	519,358	2,727,941
12	3,370,000	1,573,813	65,000	519,358	3,312,299
13	3,370,000	1,573,813	70,000	519,358	3,901,658
14	3,370,000	1,573,813	75,000	519,358	4,496,016
15	3,370,000	1,573,813	80,000	519,358	5,095,374
16	3,370,000	1,573,813	85,000	519,358	5,699,733
17	3,370,000	1,573,813	90,000	519,358	6,309,091
18	3,370,000	1,573,813	95,000	519,358	6,923,449
19	3,370,000	1,573,813	100,000	519,358	7,542,808
20	3,370,000	1,573,813	105,000	519,358	8,167,166
21	3,370,000	1,573,813	110,000	519,358	8,796,524
22	3,370,000	1,573,813	115,000	519,358	9,430,882
23	3,370,000	1,573,813	120,000	519,358	10,070,241
24	3,370,000	1,573,813	125,000	519,358	10,714,599
25	3,370,000	1,573,813	130,000	519,358	11,363,957

Figure (20)

Cumulative Revenues (SAR) for generated energy of Solar PV system for the car parking



Where the period of repayment approximately equal to 7 years and the repayment period begins to reach the value of 11.4 million riyals after 25 years [Boer, 1978]. Which is the result of Cumulative Revenues (SAR) for generated energy of Solar PV system for the car parking after installing of appropriate solar system elements especially more than three thousand solar modules, the INVERTERS, and AC Combiners for all parking zones A, B, C, G, and K.

Conclusions

Through this research studying the Economic and Environmental Impact of Installation and Operation a Photovoltaic system in Car Parks. The proposed system of renewable energy implemented for three phases (with initial cost of 3.4 million SAR) as sought by the current development plans in the Kingdom, which was strongly, reflected in the Kingdom's Vision 2030, where characterized by the following:

1. Supports the achievement of international standards and the correct vision of the Kingdom in the field of renewable energy and the preservation of the country's capabilities in the production of fossil energy, while the traditional system does not support any sustainability standards and constitutes a financial burden when replacing its parts.
2. Shows one of the ways to use solar Photovoltaics panels ON-GRID for the car parking zones, showing the value of saving the amount of 520 thousand riyals in the annual consumption of electricity, where the results and tables show the period of repayment approximately equal to 7 years. In addition, reducing the amount of carbon emissions 1300 metric tons.
3. At this stage, we can operate the solar photovoltaic systems and measurer the results and data., Where a power solar meter was installed for electrical panels of the buildings.
4. Supports the role of the university as a missionary in preserving the environment, the state's natural capabilities and the health of society, with which it shares scientific, professional, and applied responsibility that keeps pace with the Kingdom's vision of development and growth in a sound scientific manner.

5. Providing proper shading for cars parking to keep university employees' cars and students' cars from sunlight and high temperature due to spending at least 8 hours a day.

Recommendations

This project has been implemented solar system for the university parking zone about 6500m2, which supports sustainable development processes as it is considered clean energy. We recommend the use of this energy for all parking zones 140,000 m2. To obtain good and optimal results, the rules of installing solar system must be followed:

- In a way that takes advantage of the area of these PV Panels to generate electrical energy in number so that, we do not exceed the maximum value of open circuit voltage.
- Distributing PV panels to positions to obtain the maximum power (array), analyzing, and calculating this according to the available software programs.
- Grounding the entire system, connecting electrical switching panels to protect all entrances, outgoing, and adding high-voltage protection units.
- Calculation of low voltage cable clips according to the rules and the required standard. Isolate all DC cable inlets for electric shock gravity.
- Connect the power meter with building electrical switching panels professionally to protect the power grid from the source.

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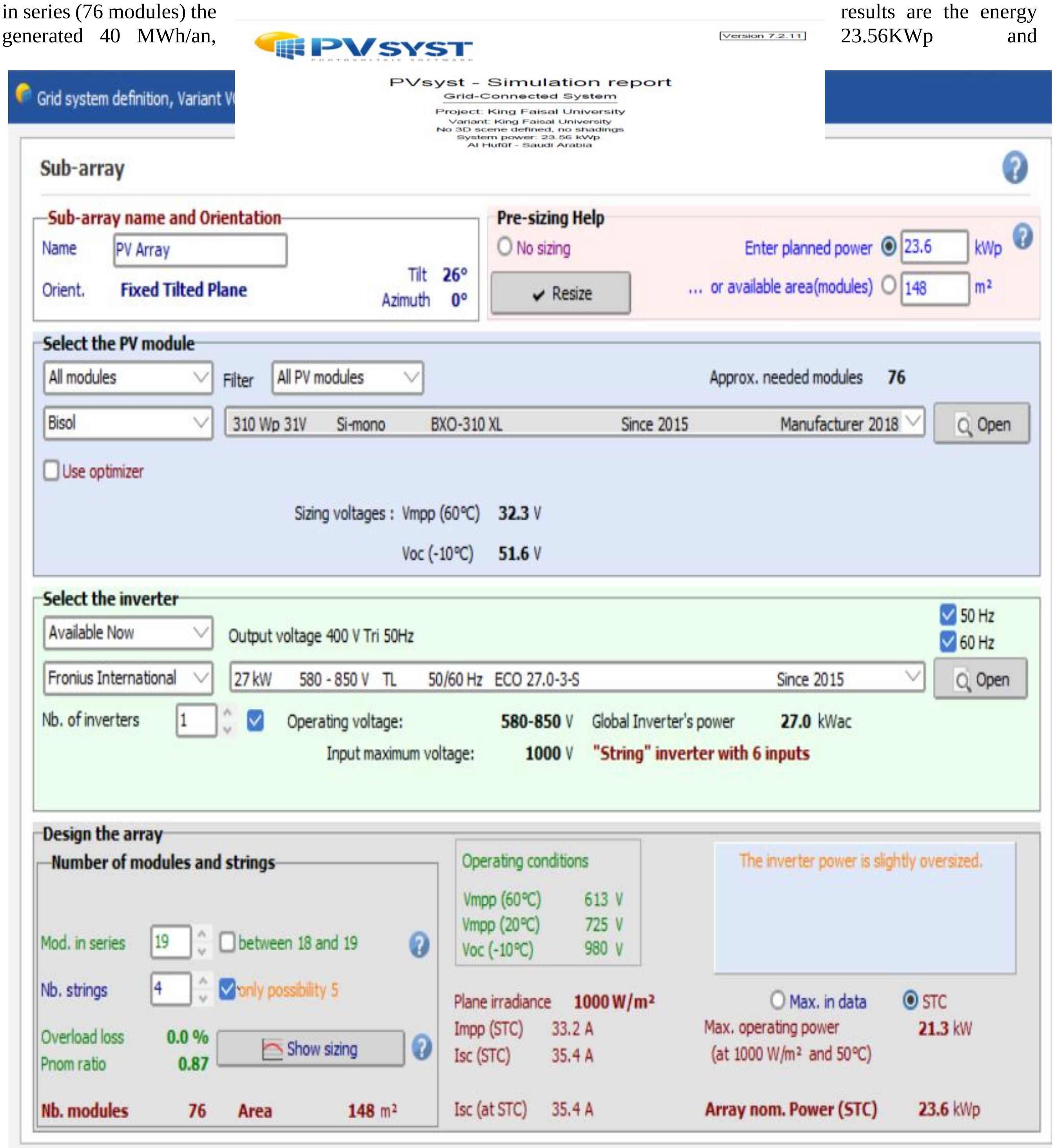
Conflicts of Interest: "The authors declare no conflict of interest." "The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results".

Appendix A

Calculation of the solar PV Energy output data with photovoltaic-software for one array with 4 strings each 19 solar modules in series (76 modules) the results are the energy generated 40 MWh/an, 23.56KWp and



19KVA as the same as model two Figure 11.**System Power 23.6 DC KW**

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PVsyst V7.2.11
VC0, Simulation date:
04/02/23 15:12
with v7.2.11

General parameters

Grid-Connected System — No 3D scene defined, no shadings

PV Field Orientation
Orientation
Fixed plane
Tilt/Azimuth 25 / 0 °

Sheds configuration
No 3D scene defined

Models used
Transposition Perez
Diffuse Perez, Meteonorm
Circumsolar separate

Horizon
Free Horizon

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Bisol
Model	BMO-310 Premium
(Custom parameters definition)	
Unit Nom. Power	310 Wp
Number of PV modules	76 units
Nominal (STC)	23.56 kWp
Modules	4 Strings x 19 In series
At operating cond. (50°C)	
Pmpp	21.29 kWp
U mpp	641 V
I mpp	33 A

Inverter

Manufacturer	Fronius International
Model	ECO 27.0-3-S
(Original PVsyst database)	
Unit Nom. Power	27.0 kWac
Number of inverters	1 unit
Total power	27.0 kWac
Operating voltage	580-850 V
Pnom ratio (DC:AC)	0.87

Total PV power

Nominal (STC)	24 kWp
Total	76 modules
Module area	124 m²
Cell area	108 m²

Total inverter power

Total power	27 kWac
Number of inverters	1 unit
Pnom ratio	0.87

Array losses

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 321 mΩ
Loss Fraction 1.5 % at STC

Module Quality Loss
Loss Fraction -0.5 %

Module mismatch losses
Loss Fraction 2.0 % at MPP

Strings Mismatch loss
Loss Fraction 0.1 %

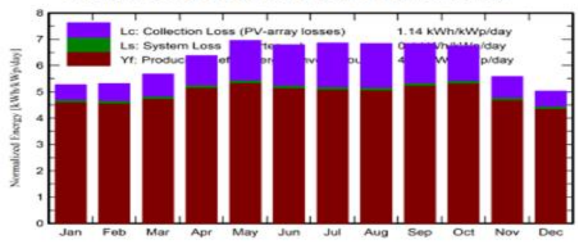
IAM loss factor
Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

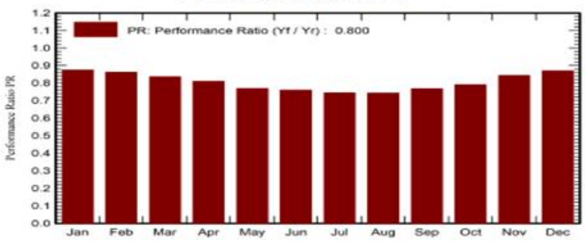
Main results

System Production
Produced Energy 42.63 MWh/year
Specific production 1809 kWh/kWp/year
Performance Ratio PR 80.02 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	122.3	49.4	14.87	163.5	161.0	3.442	3.371	0.875
February	124.9	64.2	17.40	148.7	146.4	3.082	3.019	0.862
March	161.3	84.8	22.50	176.0	173.0	3.537	3.466	0.836
April	188.6	90.9	27.60	191.4	187.9	3.726	3.653	0.810
May	228.6	105.4	34.22	215.5	211.1	3.983	3.906	0.769
June	222.4	115.0	36.85	203.7	199.3	3.718	3.646	0.760
July	229.1	107.7	38.77	212.5	207.9	3.798	3.725	0.744
August	215.5	102.7	38.22	212.0	207.9	3.783	3.710	0.743
September	189.5	66.4	34.21	205.2	201.7	3.783	3.712	0.768
October	173.8	53.6	29.49	209.3	206.0	3.972	3.896	0.790
November	128.0	47.6	21.71	167.4	165.1	3.394	3.326	0.843
December	114.4	45.6	16.57	155.9	153.8	3.263	3.196	0.870
Year	2098.5	933.3	27.76	2261.1	2221.0	43.480	42.625	0.800

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

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:0, Simulation date:
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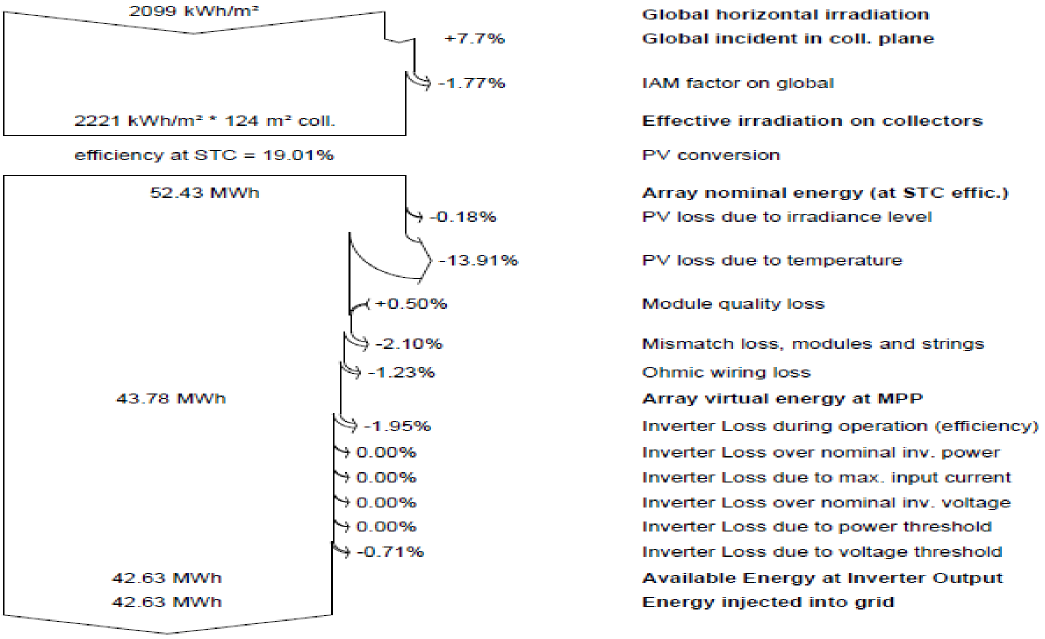
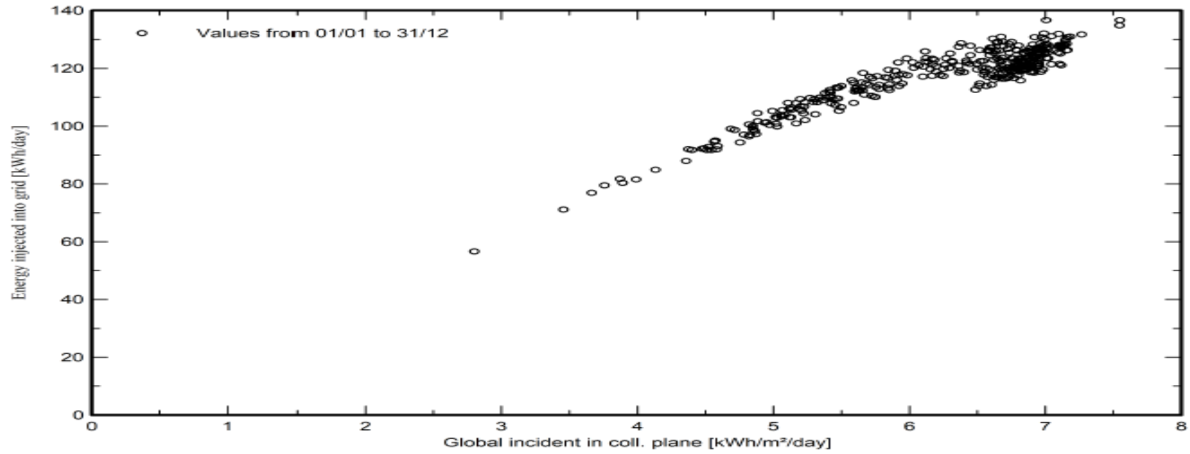
h v7.2.11

Loss diagram

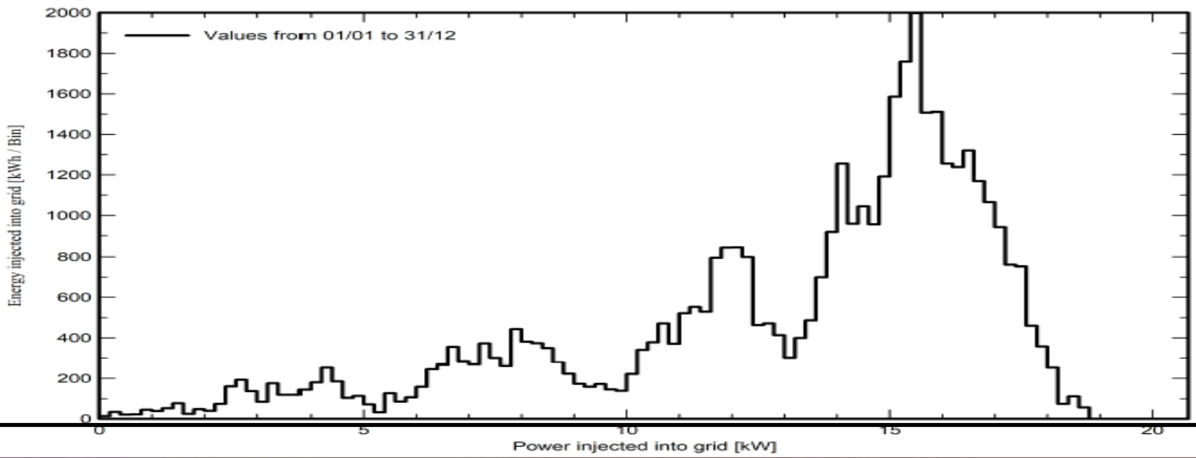


Special graphs

Daily Input/Output diagram



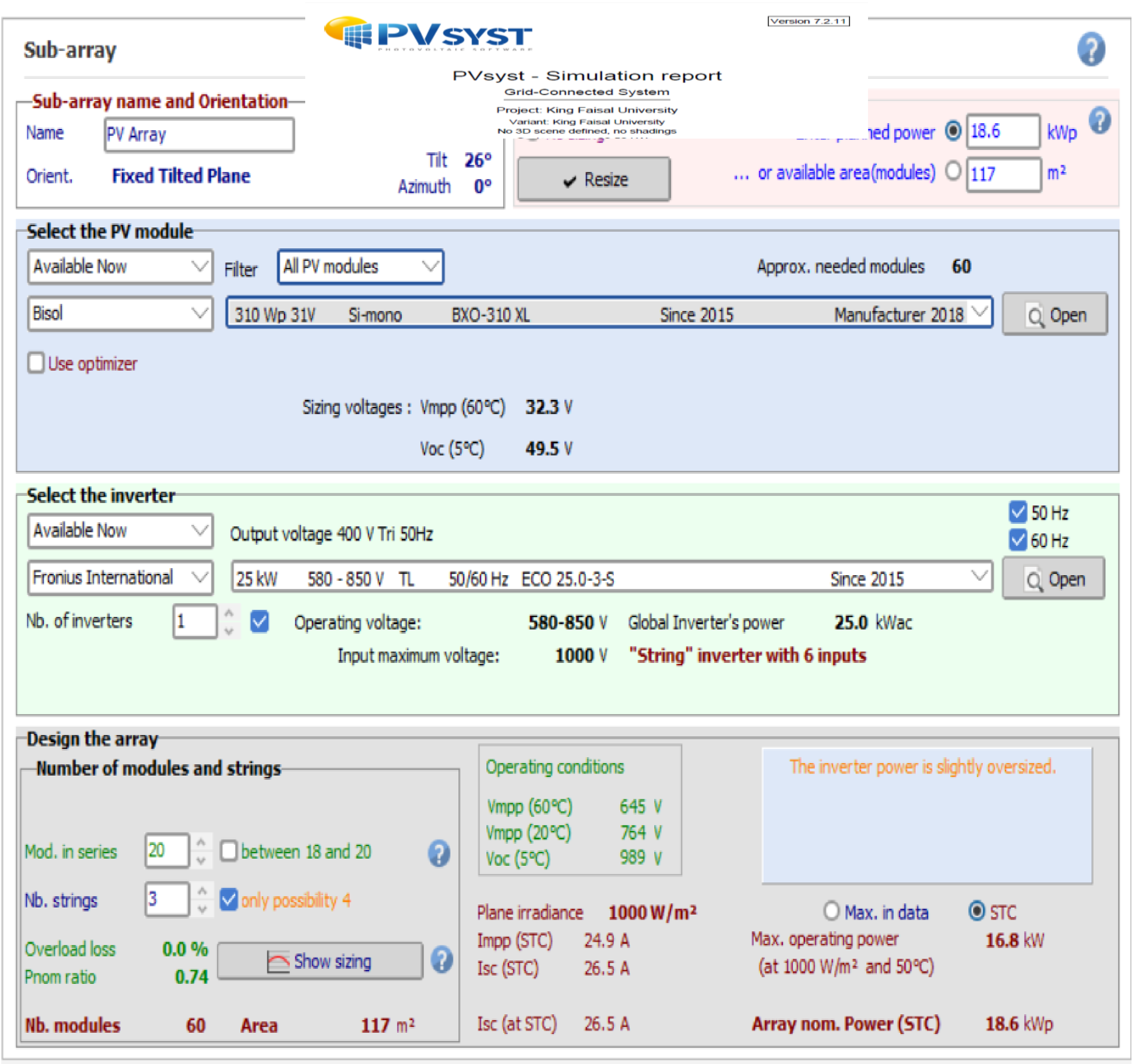
System Output Power Distribution



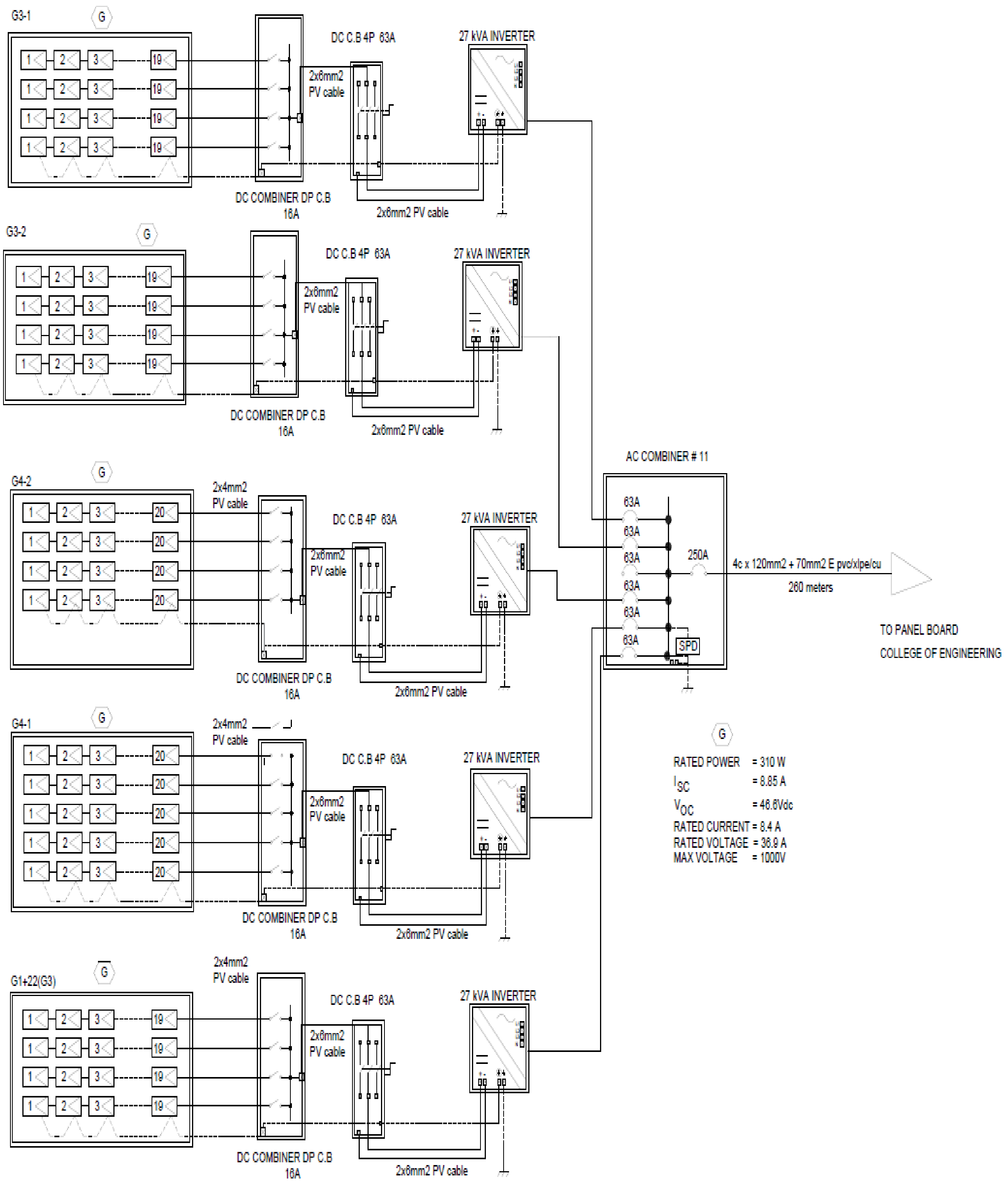
Appendix B

Calculation of the solar PV Energy output data with photovoltaic-software for one array with 3 strings each 20 solar modules in series (60 modules) the results are the energy generated 30 MWh/an, 18.6 KWp and 14.88 KVA as the same as model three.

System Power 18.6 DC KW



Appendix-Zone (G) single line diagram for DC Combiners, AC combiner, Invertors, DC CBs, DC cables, and AC Distributions cable regarding Figure 19



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"تصميم وتركيب النظام الكهروضوئي في مواقف السيارات بجامعة الملك فيصل ودراسة الأثر الاقتصادي والبيئي"

ملخص:

توضح هذه الدراسة العلاقة المباشرة بين ضوء الشمس والخلايا الكهروضوئية السيليكونية التي تحول الضوء إلى طاقة كهربائية. ومن أهم التطبيقات التي تدعم تقليل اعتماد المنشآت التعليمية في الجامعة على الشبكة العامة للطاقة الكهربائية استغلال مواقف السيارات التي يمكن أن تدعم توليد الطاقة الكهربائية لبعض الميجاوات كطاقة متجددة نظيفة، والتي تدعم أيضا عمليات التنمية المستدامة على مستوى الجامعة. ويشكل هذا المجال جزءا مهما من رؤية المملكة 2030. يتم تقييم جدوى استخدام بدائل الطاقة المتجددة بعد حساب الايرادات والاسترداد. يقدم هذا التصميم منظورا أوسع لمقارنة أنظمة الطاقة المتجددة البديلة في مواقف السيارات بعد تقدير إجمالي استهلاك الطاقة في العديد من المباني والبنى التحتية. تقدم هذه الدراسة أيضا سيناريوهات الإنتاج المستقبلية المحتملة، مع الأخذ في الاعتبار تقييم تطبيقات الطاقة الشمسية التي أجريت لعدة سنوات، والتي قد يتغير فيها نظام إنتاج الطاقة.