The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 3 || Pages || PP -38-55 || 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Grid-Connected Photovoltaic Power Systems: Domestic Simulation and Design in Kuwait (case study ofThe Public Authority Applied for Education and Training (PAAET))

Eng. Yaser Alhaddad*, Adel Alsaad**

ABSTRACT

Grid-connected Photovoltaic (PV) systems are a promising tool to provide electric power to houses in a country such as Kuwait. This optimal design and simulation of this system presented in this paper. Solar radiation is an important factor for the production of electricity by PV systems. A method for the calculation of solar photovoltaic generation capacity is developed in this project based on data of Mean Global Solar Radiation. A system design of possible plant capacity for the roof area is also developed. Monthly data is used to for the simulation and design of this system, in particular data for average solar radiation. To perform this design, MatLab/Simulink Programming are employed in this project. Toward validate the proposed configuration of the system, the results of the Analysis and Simulation are providedbased on the availability of the components in the market and their specifications.

Date of Submission: 11 March 2016 Date of Accepted: 30 March 2016

I. Introduction:

The sources of renewable energy provides a potentially promising and far less harmful alternative to traditional methods of electricity production. Such sources has the potential to reduce environmental impacts involved in the production process as well as the greenhouse emissions. Power plants fired by natural gas emit 0.75Kg of carbon and coal plants produces emits 1.05Kg of carbon [1]. Fossil fuel burning causes grave environmental harms and a great deal of these can be avoided by the use of renewable resources as the environmentalimpact is reduced by every kilowatt-hour (kWh) of electricity produced in renewable resources.A great amount of rays are sent from the sun on a daily basis and while the earth receives approximately just under 50% of that radiation, the atmospheric gases absorbs about 20% of it and the rest 30% reflects back to the space [2].

The daily rate of this solar radiation equals nearly 3.838 x 1023 kW/sec [3]. At the atmosphere boundary, this power reaches to approximately 1.4 kW/m2 and a great deal of it constitute electromagnetic radiation transmission. The amount of solar energy that can be received by, for example, one square meter of the surface of the each equals about 1KW and on average this makes 0.5 after crossing the atmosphere during the daytime hours.Photovoltaic solar energy can highly likely be used domestically in a country such as Kuwait, where the sun appears approximately 3600 hours every year [4] and, thus, the surface of the earth receives a great deal of the radiation of the sun power during most days of the year. Kuwait, which is rich with oil, is a Middle East state with 4.1 population and an area of 17820 Km^2. Local people of Kuwait are nearly 1.2 million and the rest are immigrants.

II. Photovoltaic (PV) systems

The PV generator constitutes of a number of solar panels which are interconnected electrically. Manufactures provide the PV panels at standard tested conditions (STC) in relation to their nominal peak power. The total installed power of the system can be calculated by summing the nominal peak power of all panels in the system [7].

The grid-connected system is comprised of an inverter and modules. The direct current (DC) electricity that is produced by the PV system is transformed by the inverter into alternating current (AC) electricity and this put into synchronization with the mains supply of electricity. At all times, the grid is fed with the excess electricity produced. Grid connected inverter must be designed in a way that allows it to perform well at peak power value. The inverter also must be able to tackle different issues including the quality of the power, the operation of islanding detection, grounding, long life and Maximum power point trackingMPPT [8].

The gird injected energy has to be optimized by the inverter maximum power and this must equal the overall PV generator power. As the anticipated irradiance in the location where the PV system installed is below the nominal or standard irradiance, it has recently been observed that the maximum power of the inverter is chosen to be higher than that of the nominal PV generator. This has been known as the inverter under sizing as is discussed in [7] and [8]. The standard irradiance conditions are in line with nominal power of the PV generator. In low irradiance condition, the PV produces energy at one part of the nominal capacity and, therefore, under part load conditions, the inverter works with lower system efficiency [7].

Figure1: Proposed direct grid-connected PV System [14]

This paper provides an analysis and design of a grid-connected photovoltaic power system that can be used domestically in houses in the state of Kuwait. MatLab/Simulink programming will be used to test the PV strings possible capacity of a 162 kW Plant. Moreover, the temperature and irradiance effect will be analyzed by the use of Simulink programming.

III. Methodology :

The research tools for this paper focused on the inputs for the simulation process and the required calculations. The probability of solar photovoltaic generation in Kuwait was calculated, depending on the annual solar radiation. The calculations showed that the output efficiency of the PV module was 97%. However, the PV grid connected systems are generally designed to supply 30% to 70% of the power demand.The availability of solar energy was supposed to last for six hours during the normal day of the design. As for the PV grid-connected system, it was designed based on the calculated plant capacity in the available area.

a. Data collection:

The Kuwait Institute for Scientific Research (KISR) measurement for solar radiation in Kuwait annually with maximum (1006$^{W}/_{m^2}$), minimum (0.013 $^{W}/_{m^2}$) with an average of (222.32 $^{W}/_{m^2}$).Atmospheric temperature measurement in Kuwait annually 52.55˚C and 8.05˚C respectively according to The Kuwait Institute for Scientific Research (KISR).The Public Authority Applied for Education and Training (PAAET)used as a case study for our project. Furthermore, the maintenance and engineering building in PAAET is considered as one of many buildings in Kuwait representing a high electrical load.

b. The Site:

Kuwait is one of the Arabian Gulf countries in western Asia. The size of the country is about 17820 Km^2,and the estimated population of Kuwaiti nationals is 1.2 million and 2.8 million foreigners. The capital is Kuwait city, which is located at 29.3697° N, 47.9783° East longitude. Kuwait is an ideal area for the generation of solar energy because it is in a vast plain area. It has a plenty of sun rays during the year, and the estimated average of daily solar radiation in flat areas on the coast is 2.7 kilowatt hours per square meter per day (kWh/m²/day) and 3.4kWh/m²/day in the south region [4].

IV. Calculation

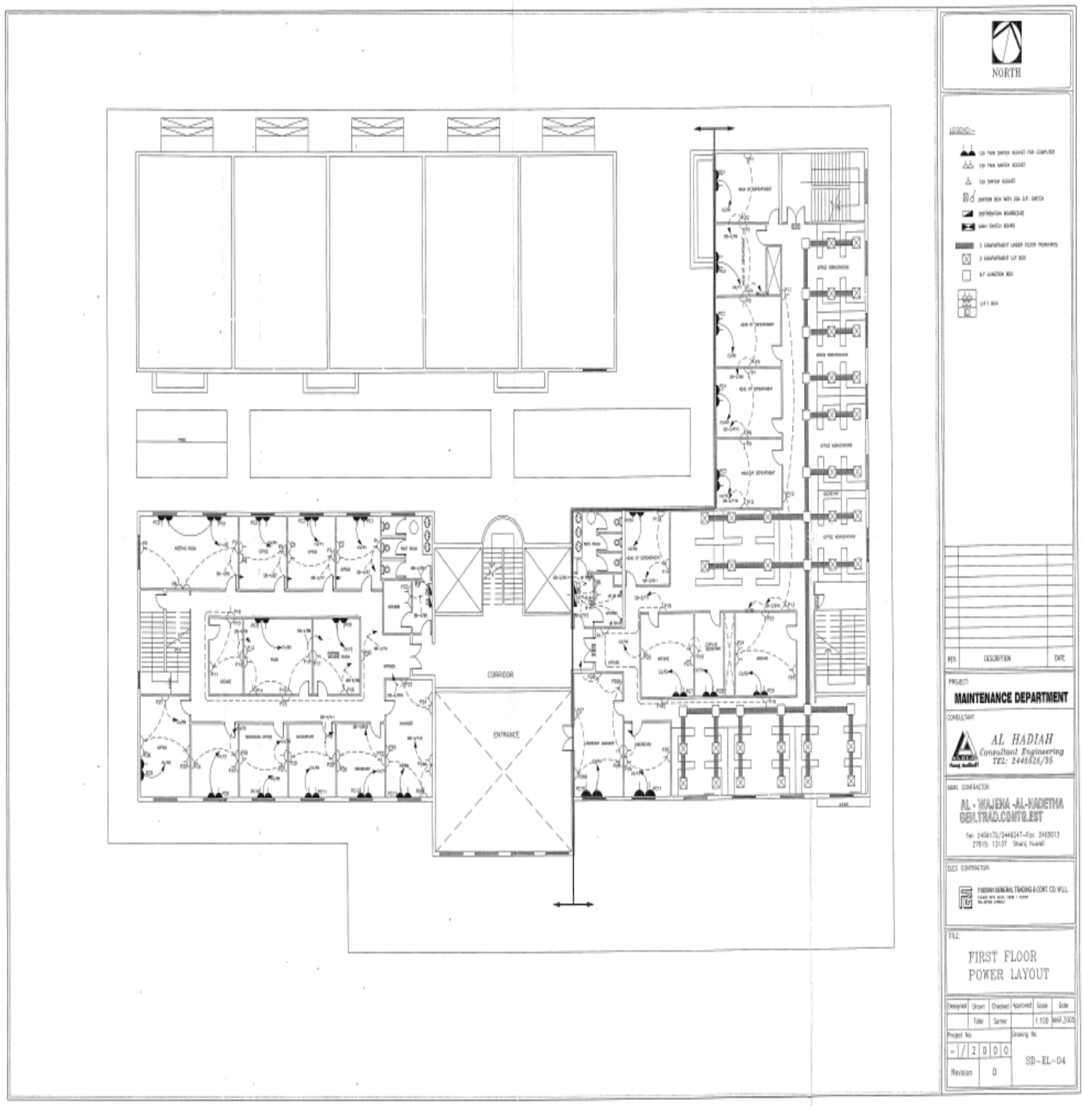
a. Load Profile:

The number of PV panels might be affected by change of the load during night and day, which makes load profile very important for the inverter size and design process. Table (3) below shows the load profile of the Public Authority Applied for Education and Training (PAAET). The PAAET offers services to more than 1000 technicians and employees in a building, which should have a study of the PV system.

The consumption load of electricity of PAAET includes lightening, electrical equipment and air conditioning. Importantly, the load consumption of electricity varies by season and the type of everyday activities. The overall power load consumption of the PAAET is 340 kW. The size of the roof of the building, which is the focus of the study, is nearly 1037 m^2.

Table 1: The Building (PAAET) Data Information

The Building (PAAET) Data Calculation (2)		
Floor	**Lights KW**	**Air-Condition KW**
First	48.25	
Second	19.29	
workshops	30.64	
Sum	98.18	241.9
Final Total Load Power (KW)	340.08	



b. Energy:

The possible plant capacity which will be on the roof of the PAAET building was calculated by considering the PV module efficiency 97%. This value is assumed to be the average annual solar insulation in Kuwait, and the solar energy is assumed to be available for six hours throughout the day [10]:

$$\textbf{average solar in Kuwait} = 222.32\ Wh/m^2/day\ = 1333.92\ W/m^2$$

After estimating the (potential, building effective area, plant possible capacity, and energy generated). The grid design which is connected to the solar PV power plant is made.

$$\textbf{\textit{Building Effective Area}} = \textit{Building available area on the roof} \times 0.7$$
$$= 1037 \times 0.7 = 725.9\ m^2$$

$$\textbf{\textit{Plant Possible Capacity}} = 60\% \times \textit{Total load of PAAET building}$$
$$= \left({}^{60}/_{100}\right) \times 340.08 = 204.048\ KW$$

$$\textbf{\textit{Energy Generated Per Day}} = 6\ \textit{hours} \times \textit{Plant Possible Capacity}$$
$$= 6 \times 204.048 = 1224.288\ KWh$$

A system for generating photovoltaic solar energy was installed to the roof of the PAAET building. The estimated generated energy is shown in Table (4):

Table 2:energy generated from available roof-top area on PAAET

Energy Generated on the Building	
Building available area on the roof (m2)	1037
Building effective area (m2)	725.9
Output Average Peak (W/m2)	222.32
Plant Possible Capacity (KW)	204.048
Energy Generated per Day (KWh)	1224.288
Energy Generated per month (KWh)	36728.64

V. PV Grid Connected System and Sizing

PV grid connected systems usually provide about 70% of the overall electrical power demand while the other 30% is supplied by the utility power. The overall power of the PV system was estimated to be 204.048 kW. Thus, the assumption in this this study is that PV system supplies around 60% of the overall required energy.

a. PV Panel Sizing:

PV modules are sized under standard test conditions. The nameplate provided by the manufacturer forms a module output which is measured under a factory controlled conditions. Under standard test conditions, solar irradiance is 1,000 W/m^2 and the module temperature is 25 C^o. An interesting relative comparison between the module and sizes is provided by the wattage of standard test conditions, but it is not the same of real world measure. According to the information provided by the manufacturer, a design criteria for PV module is made, and the specifications of the solar panels, which were used, are shown below:

Table 3: specifications for solar panels

Specification for Solar Panels	
KYOCERA SOLAR Inc. (KD 300-80 F Series)	
Maximum Power Current (I_{mp}) (Amp.)	6.47
Open Circuit Voltage V_{oc}) (V)	45.5
Short Circuit Current (I)	7.04

Rated Power (P_{max}) (W)	234
Temperature Coefficient (P_{max})	-0.45
Temperature Coefficient (V_{OC}))	-0.36
Temperature Coefficient (I_{SC}) mA/C°	0.06
Maximum Power Voltage (V)	36.2
Minimum Power (P_{minsc}) W	180
Max System Voltage (V)	600
Series Fuse Rating A	15
Electrical Tolerance %	5
PTC Rating W	290.4
Module Efficiency %	17
Module Area (m^2)	1.18
Cell Efficiency %	19.7

According to the data, the available area of the roof (725.9m^2) where is the solar PV power plant might develop up to 204.048 KW. As for the numbers of the required PV modules, they are calculate the following:

$$\textbf{Number of modules} = {}^{P_{PV}}/_{P_{max}} = {}^{204.048 \times 10^3}/_{234} = 872\ module$$

By using the module area and the effective area, the calculation is:

$$\textbf{Number of modules} = {}^{Effective\ Area}/_{Module\ Area} = {}^{725.9}/_{1.18} = 615.17\ module$$

There is also a connected series-parallel combination of the modules as is shown below:

$$\textbf{The number of modules in series} = {}^{500}/_{V_{\max\ (p)}} = {}^{500}/_{36.2} = 13.8 \cong 14\ modules$$

$$\textbf{The number of modules in parallel} = {}^{(P_{PV} \div 500)}/_{I_{\max\ (p)}} = {}^{408.096}/_{6.47} = 63.08 \cong 63\ modules$$

Finally, we calculate the output voltage and current by the following equations:

$$\textbf{Output Voltage} = maximum\ power\ voltage \times number\ of\ PV\ in\ series$$
$$= 36.2 \times 13.8 = 499.56 \cong 500\ volt$$

$$\textbf{Output Current} = maximum\ power\ current \times number\ of\ PV\ in\ parallel$$
$$= 6.47 \times 63 = 407.61 \cong 408\ Amp.$$

Table 4: specifications for solar panels

Solar photovoltaic power plant calculated specifications	
Number of modules	615.169
Effective area (m)	725.9
Output voltage (V)	500
Output Current (A)	408
Capacity of the plant (W)	204000

b. Sizing of the Inverter:

To be able to handle the overall number of Watts required at one time, there should be a large inverter. The inverter is usually used to satisfy the requirement for the existence of an AC power output in the system. Importantly, the chosen PV modules for grid-connected systems decide the choice of the inverter. Also, the rated power should be more than less than the supplied power due to the fact that the inverter is rated at 210 kW to provide the required 204.048 kW PV output rated power. The rating of current inverters is for the maximum of input DC current, input DC power or the specified output power. Hence, the inverter was chosen according to the selected PV modules.

Table 5: The specifications of the inverter

Inverter specifications	
Power Gate Plus	S-Type UL
Nominal Output Current (A)	216
Output Max. Current (A)	505
AC Output Nominal Voltage (V)	240
AC Output Voltage Range (V)	211~264
DC Max. Input Power (KW)	172
DC Max Voltage (V)	600
Input Max. Current (A)	830
Output Nominal Power (KW)	210
Power Factor	> 0.99 %
Dynamic Power Factor Control	± 0.8
Efficiency	96%
Operating Consumption	<100 W
Operating Temperature	Opt. -40º C to +50º C
THDI (at nominal output power)	3%

c. Specifications of System Sizing:

The designed system sizing and the specifications of 204.048kW power plant are given in the table below:

Table 6: The specifications of the Solar panel

Solar panel specifications	
Voltage (V)	55.8
Current (A)	3.59
Efficiency	17%
Rated Power (W)	200
Temperature C°	25
Area of single panel dimension (mm)	1.18

Table 7:The Specifications of the Grid

The Network (Grid) specifications	
Frequency (Hz)	50
Number of phases	3-phase
Voltage rating (V)	380

VI. Simulink Output of a Designed Grid-connected PV Panel

A diagram of the general block of a PV model that uses Simulink is shown in Figure (7) below. As is shown in the figure, the final model is built by the connection of the sub-models. PV model inputs include the level of variable solar irradiation (G) and the variable values of temperature (T). The function of the array voltage (*V)* is the output current (*I*). PV equation is given as follows:

$$I_{operation} = I_{Ph} - I_D = I_{Ph} - I_{sat.}\left[e^{\frac{q(V+IR_s)}{nKT}} - 1\right] \quad 4$$

R_s: The series resistance [Ω],
V: the operation voltage [V],
I_{Ph} : The light current [A],
$I_{sat.}$: The diode reverse saturation current [A],
I: the operation current [A].
q: Charge of one electron 1.602 x10^{-19}
n: Diode idealizing factor,
T : Junction temperature in Kelvin.
K: Boltzmann's constant =1.38 x10^{-23}J/K.

There is detailed discussion of PV array modelling for MatLab/Simulink Environment [12] [13].

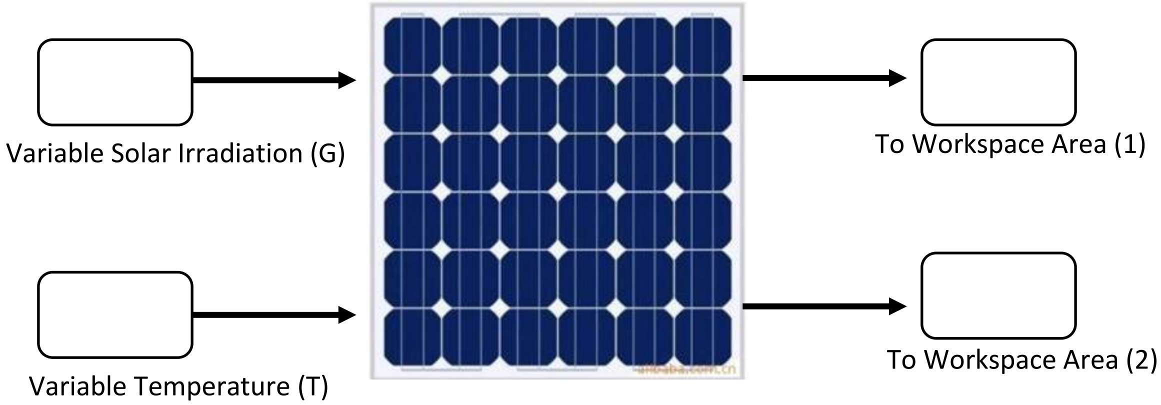


Figure7: PV module modelled in Simulink

The model consists of sixty-three modules connected in parallel and fourteen modules connected in a series, and there is the manufacturer's specification shown on the nameplate (See Table 5). The output voltage is V_{PV} and the output current isI_{PV}, whereas the inputs are the module voltage, irradiation and the operating temperature.

The improved model and the characteristics of the PV modules are shown as follows:
The characteristics of the PV module I-V output with varied irradiation and constant temperature are illustrated in Figure (8).

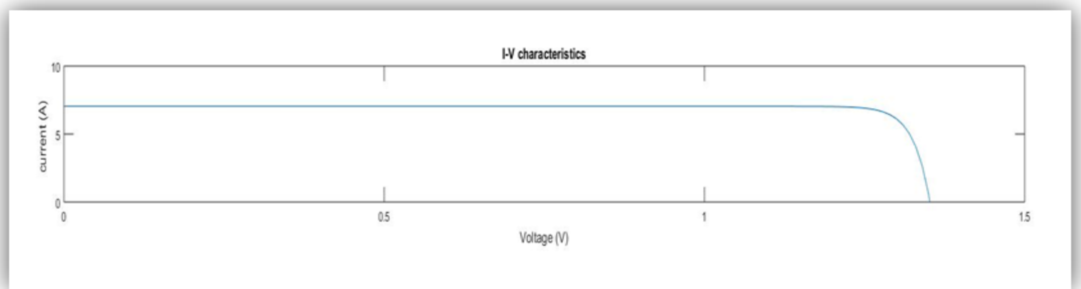


Figure8: I-V Characteristic curves at varied levels of insulation

The characteristics of the PV module P-V output with varied irradiation and constant temperature are illustrated in Figure (9).

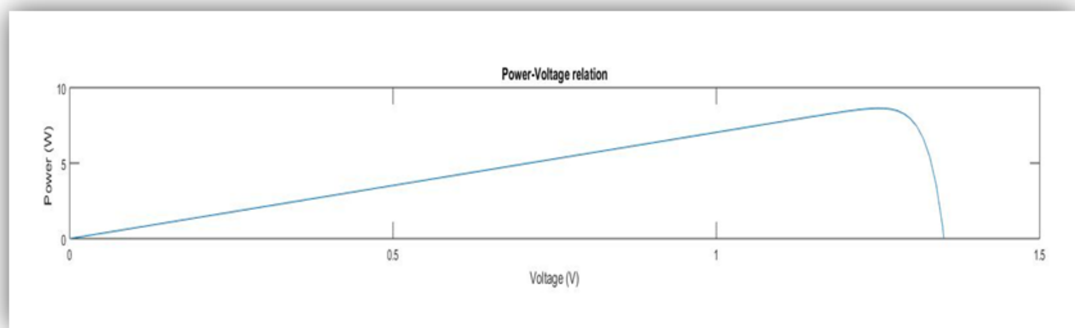


Figure9: P-V Characteristic curves at varied levels of Insulation

The current output goes up when irradiation goes up, and there is also an increase in the voltage output vice versa. By keeping the temperature constant, when there is an increase in irradiation, there will be an increase in output power as well. When there is constant irradiation of 222.32W/m^2 andvaried temperature, the voltage output will consequently varies.

There is a margin increase in the current output when the operating temperature goes up. There is a drastic decrease in the voltage output, which leads to net decrease in power output with an increase in temperature.

The characteristics of the PV module maximum power point tracking when the current and the voltage intersect at a point correspond to the “knee” of the curveis illustrated in Figure (10).

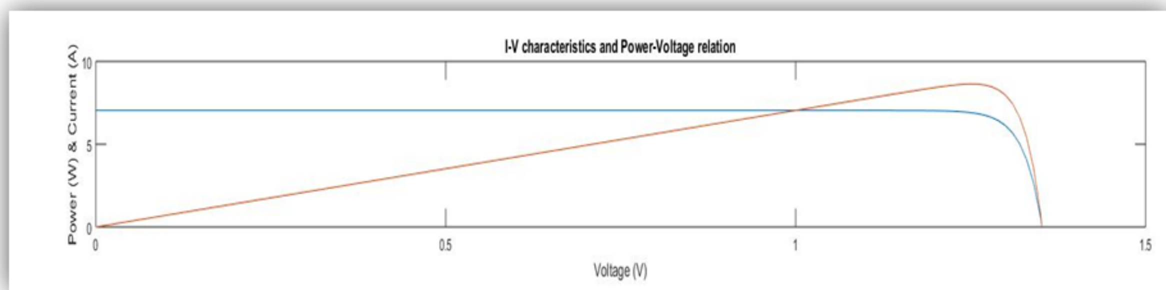


Figure10: P-V Characteristic curves Maximum Power Point Tracking (MPPT)

a. <u>Domestic (PAAET) simulation PV connected module:</u>

Our domestic simulation PV connected module using MatLab/Simulink isillustrated below in figure (11).

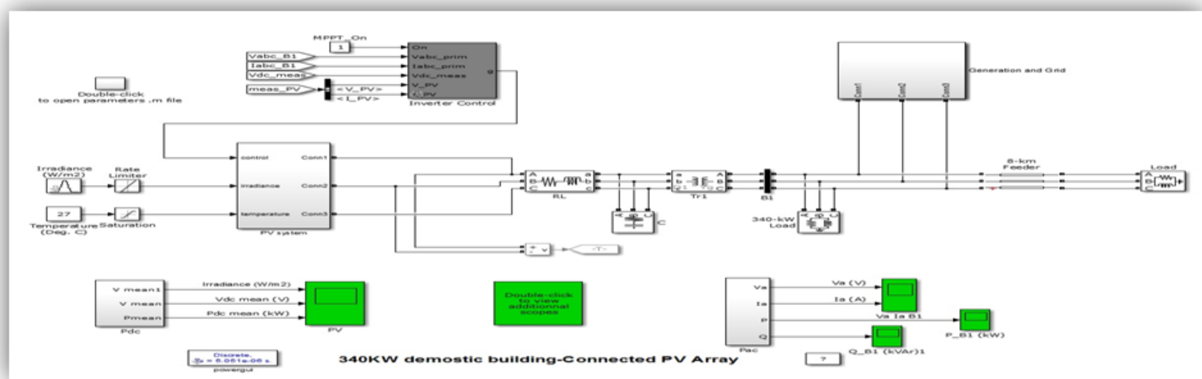


Figure11: Domestic (PAAET) simulation PV connected module

i. PV Array

The PV array system consists of 63 parallel modules. And has 14 modules connected in series. Module menu allows plotting the I-V and P-V characteristics of the whole array or for a selected module.

ii. Inverter Control

Five major Simulink-based subsystems used to control the system:

- MPPT Controller: The Maximum Power Point Tracking (MPPT) controller in order to obtain a DC voltage which will extract maximum power from the PV array, the system automatically varies the V_{DC} reference signal of the inverter V_{DC} regulator.
- Current Regulator: The regulator determines the reference voltages required for the inverter based on the current references Id and Iq (reactive current). Iq reference in this work is set to zero.
- V_{DC} Regulator: Determine the (active current) Id required as current regulator reference.
- PLL & Measurements: voltage/current measurements and synchronization requirements.
- A 250-kVA 250V/25kV three-phase transformer is used to connect the inverter to the utility distribution system.

iii. Utility grid

Modeling the grid as a typical Kuwait city distribution grid, consisted of an equivalent 120-kV transmission system, and two 25-kV feeders, beside loads and grounding transformer.

b. MatLab/Simulink Simulation Results:

i. DC Output:

The various scopes show the resulting signals after running the simulation.Avery well correspond value appeared in the simulation as comparing to PV module manufacturer specifications.The operating temperature is 27˚C and the initial input irradiance value to the PV array model is 550 W/m^2. We will get a PV voltage (V_{DC}_mean) of 545V after around$t = 0.2\ sec$. When steady-state is reached, extracted power (P_{DC}_mean) from the array is 144.5 KW.

Due to the operation of MPPT, and in order to extract maximum power from the PV array, the controlling system reduces the referenced V_{DC} to 500V.

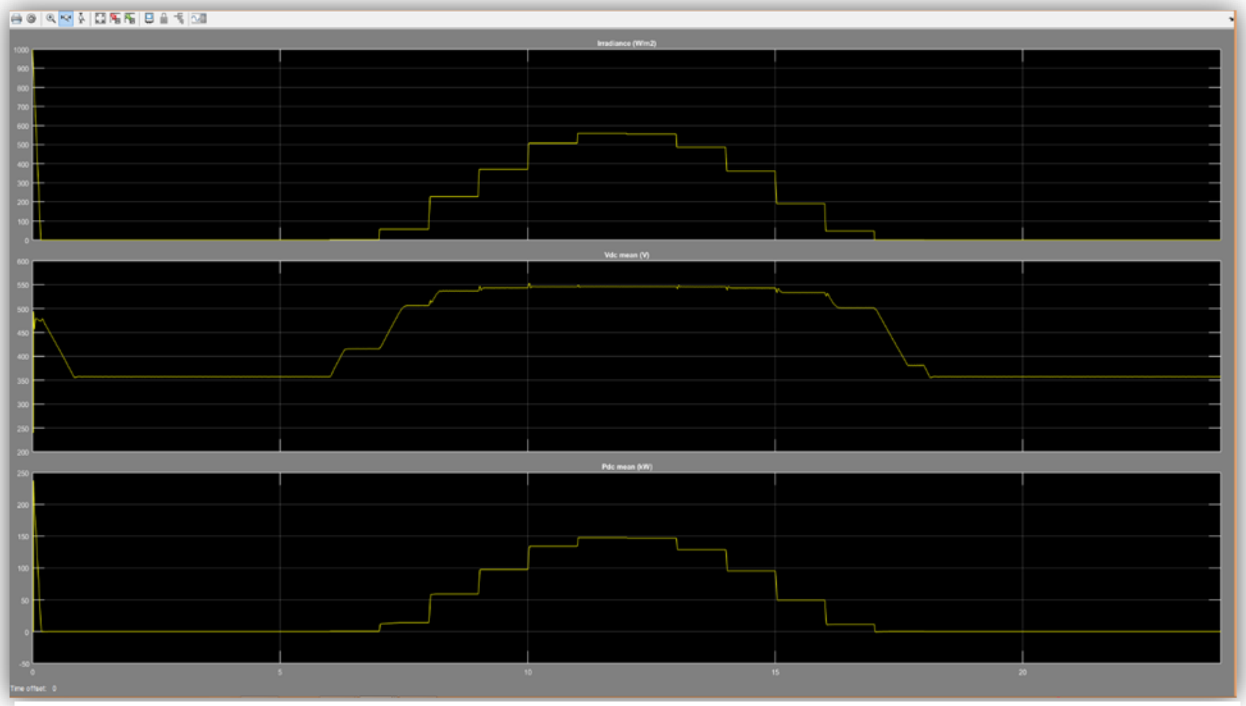


Figure12: Maximum DC Output Curves

ii. AC Output:

At a temperature of 27˚C and different range of irradiation, MatLab/Simulink measured the mean output power (P_{ac}) (V, I) to be 144.5 KW as illustrated in figure (12) below:

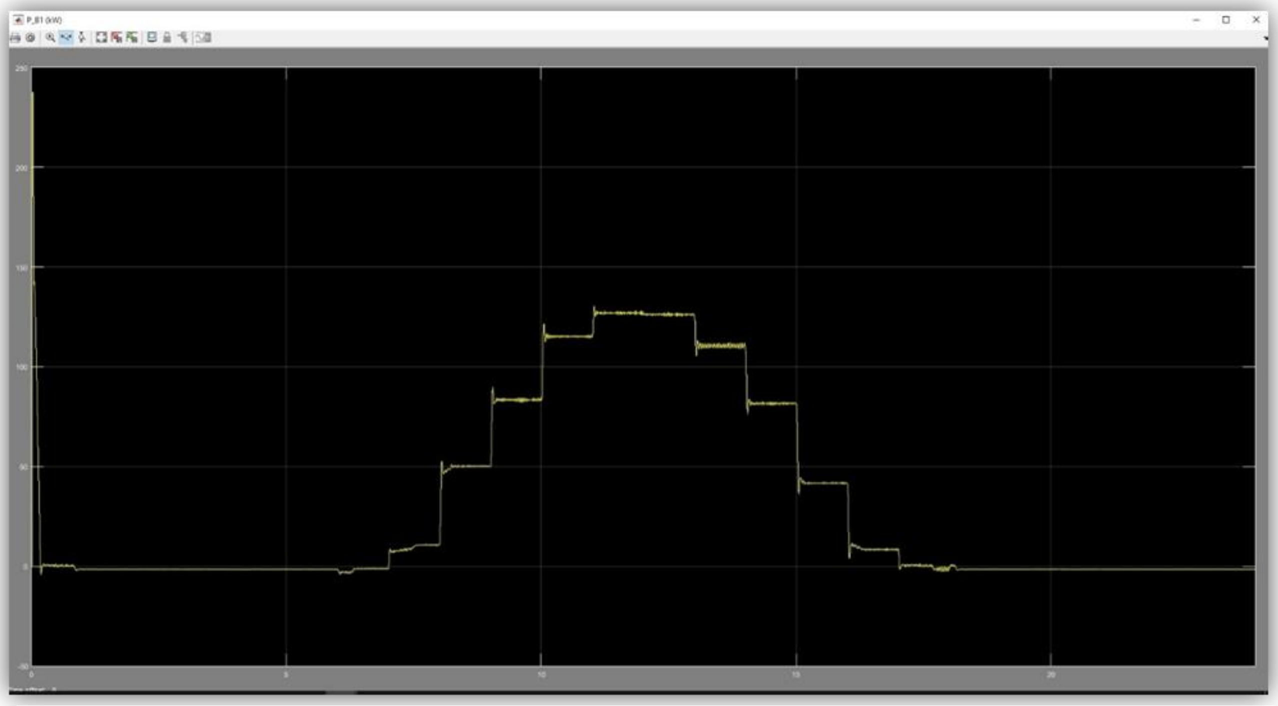


Figure13: Peak output power (Pac) curve

The mean output power (P_{ac}) represent the peak value of the output power. On the other hand the calculation in chapter 5 showed that the RMS value is 204kw.

$$AC\ Output\ \ Power_{RMS}\ = 144.5 \times \sqrt{2} = 204.354\ KW$$

After verification, the calculated results matched with the MatLab/Simulink data output curves.

V. Conclusion

This paperis a case study in Kuwait, which consist of providingthe electric load for the Public Authority Applied for Education and Training (PAAET) building through a PV grid-connected system. Kuwait is a countryin the Middle East with rich solar resources, so it has a good potentials for PV powered projects.The designed photovoltaic grid total capacity is 204.08 KW whereas PAAET's total load power is 340.08 KW.Accordingly our PV grid can provide 60% of the total load power which is our target in this study. The design of the solar panel (which consist of 615 modules; 63 in parallel and 14 in series) was based on MatLab/Simulink. When comparingthe simulation value of the AC mean output power of 144.5KW which is equivalent to 204.354KW in RMS and the calculated result of 204.08KW, the values are identical. Figure (8) and Figure (9) showed the PV's characteristic curves at varying insulation levels and constant cell working temperature.
Simulink was used to size and simulate the designed PV system modules, which resulted in a system of 210KW inverter and 204KW of PV.

References:

[1] Plesser .R and Hefferman J,"Light and shadows"www.learnnc.org. [access date 10 march 2015].
[2] U.S. Emission Data, Environment Energy-Related Emission Data & Environmental Analysis, Energy Information Administration, http://www.eia.doe.gov/environment.html [access date 20 march 2015].
[3] Chiemeka I. U and Chineke T. C, "Evaluating the global solar energy potential at Uturu, Nigeria", International Journal of Physical Sciences Vol. 4, Issue 3, pp. 115-119, 2009.
[4] F. Almonacid, C. Rus, P. Perez, and L. Hontoria, "Estimation of the energy of a PV generator using artificial neural network," Renewable Energy 2009, vol. 34, pp. 2743-2750.
[5] I. M. Saleh Ibrahim, The forth Arab International Solar Energy Conference, Amman, Jordan, 1993.

[6] G. Makrides, B. Zinsser, M. Norton, G. Georghiou, M. Schubert, and J. Werner, "Potential of photovoltaic systems in countries with high solar irradiation," Renewable and Sustainable Energy Reviews 2010, vol. 14,pp. 754-762.

[7] Johann Hernandez, Nelson L. Diaz, and Gerardo Gordillo. Design Dimensioning Model For Grid-Connected Photovoltaic Systems. Electrical Power & Energy Conference (EPEC), 2009 IEEE, pp 1-5, Lab. de Investig. en Fuentes Alternativas de Energia (LIFAE), Univ. Distrital F.J.C., Bogota, Colombia, Oct. 2009.

[8] Guillermo Velasco, Francesc Guinjoan, Robert Pique and Juan Jose Negroni. Sizing Factor Considerations for Grid-Connected PV Systems Based on a Central Inverter Configuration. IEEE Industrial Electronics, IECON 2006 - 32nd Annual Conference, pp 2718 - 2722 Dept. of Electron. Eng., Polytechnic Univ. of Catalonia, November. 2006.

[9] http:/www.wholesalesolar.com/solar-panel.html.

[10] http://www.bandasolar.com/insolationLevel.html.

[11] http://www.tripoli-libya.climatemps.com/sunlight.php.

[12] Mustafa.A. Al-refai "Matlab/Simulink Model for Simulation of Photovoltaic Module" First Conference and Exhibition on Renewable Energies and Water Desalination Technologies.

[13] Mustafa.A. Al-refai " Matlab/Simulink Simulation of Solar Energy Storage System" World Academy of Science, Engineering and TechnologyVol:86 2014-01-04.

[14] http://www.offgridbydesign.com/solar-information/grid-tied-pv-systems

[15] http://www.offgridbydesign.com/solar-information/grid-tied-pv-systems

[16] http://ecmweb.com/green-building/highs-and-lows-photovoltaic-system-calculations - access on 10-3-2015

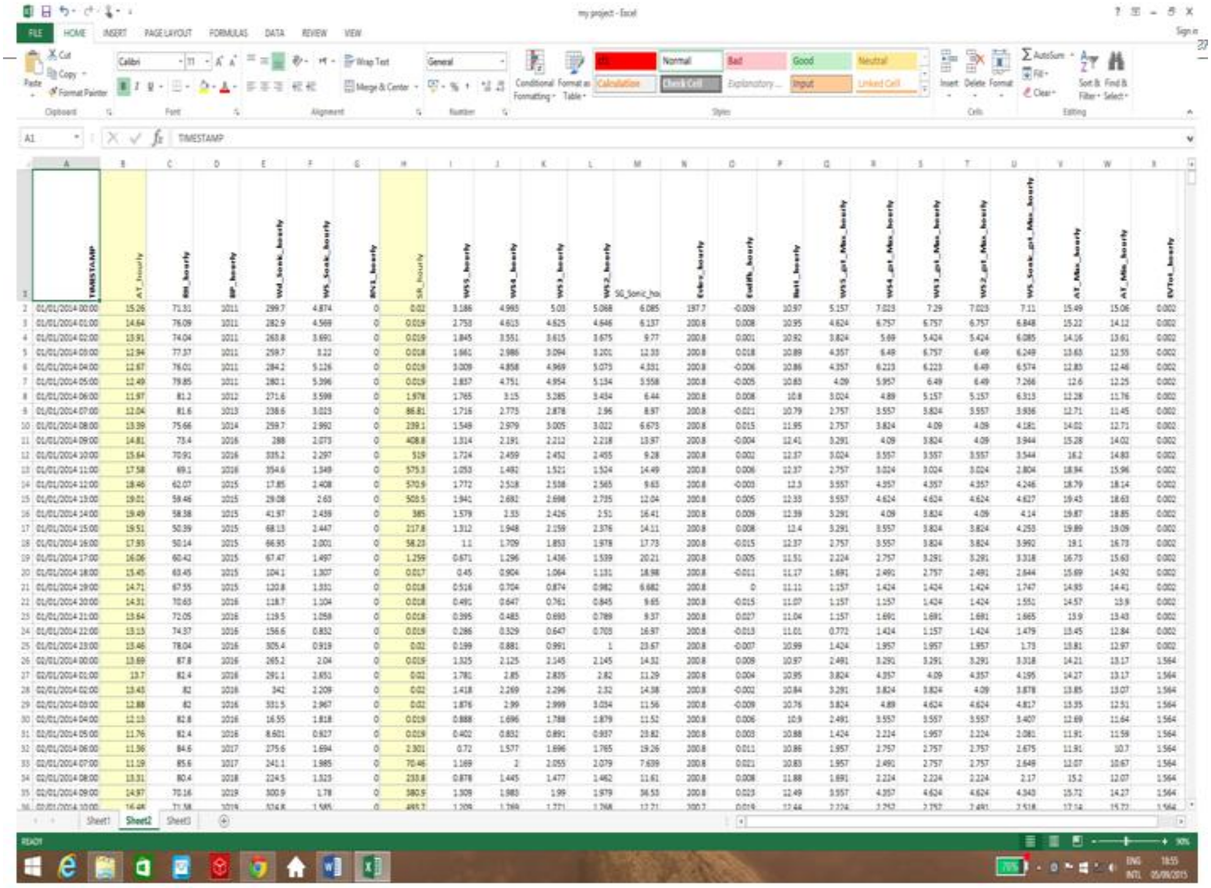
[17] http://ecmweb.com/green-building/highs-and-lows-photovoltaic-system-calculations - access on 10-3-2015

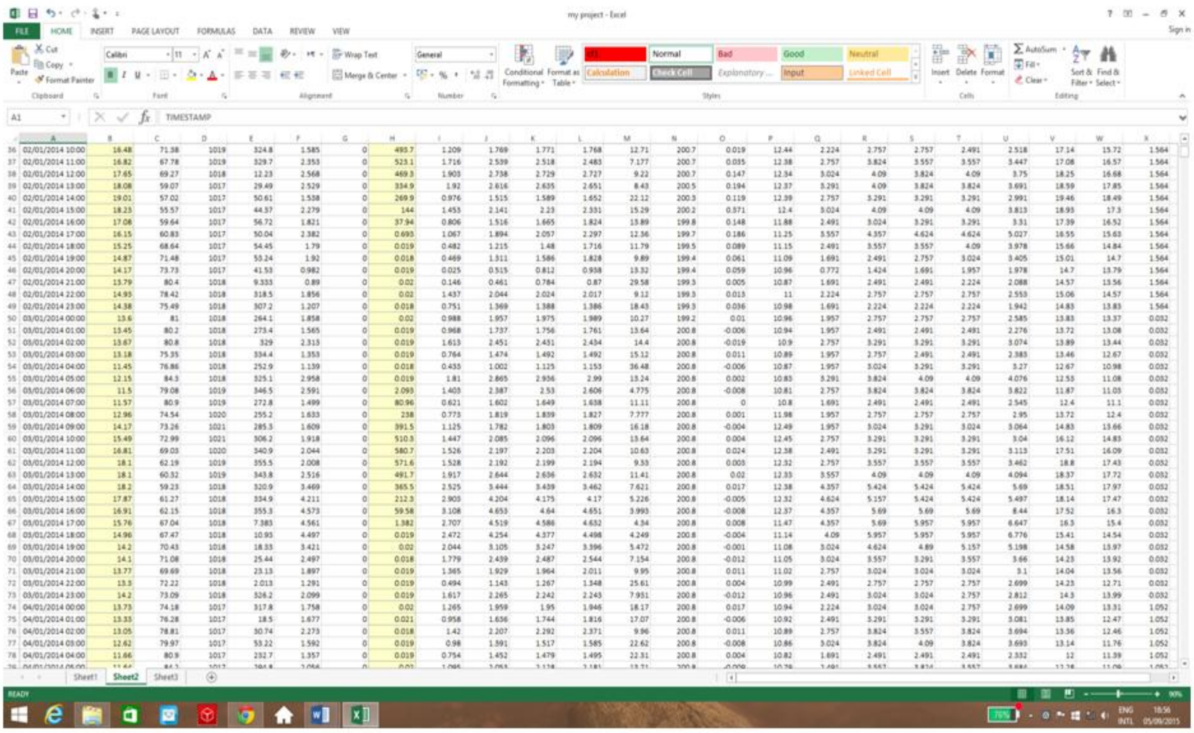
[18] http://ecmweb.com/green-building/highs-and-lows-photovoltaic-system-calculations - access on 12-3-2015

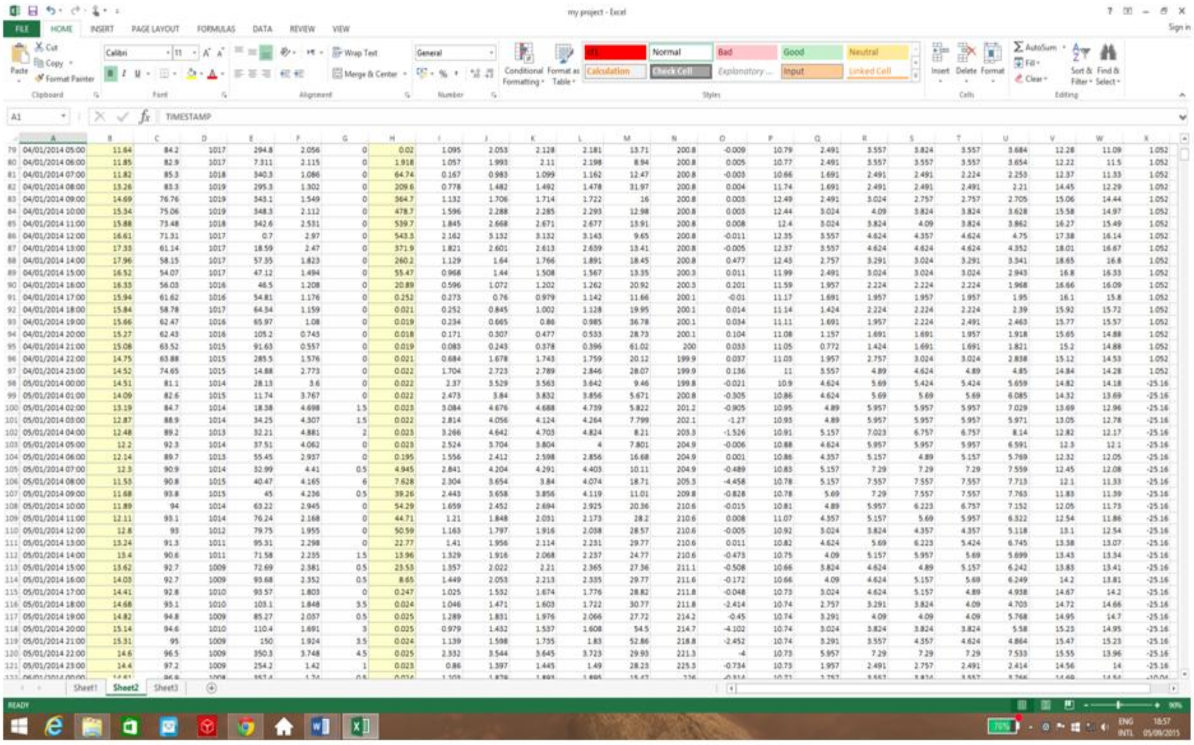
VII. Appendix:

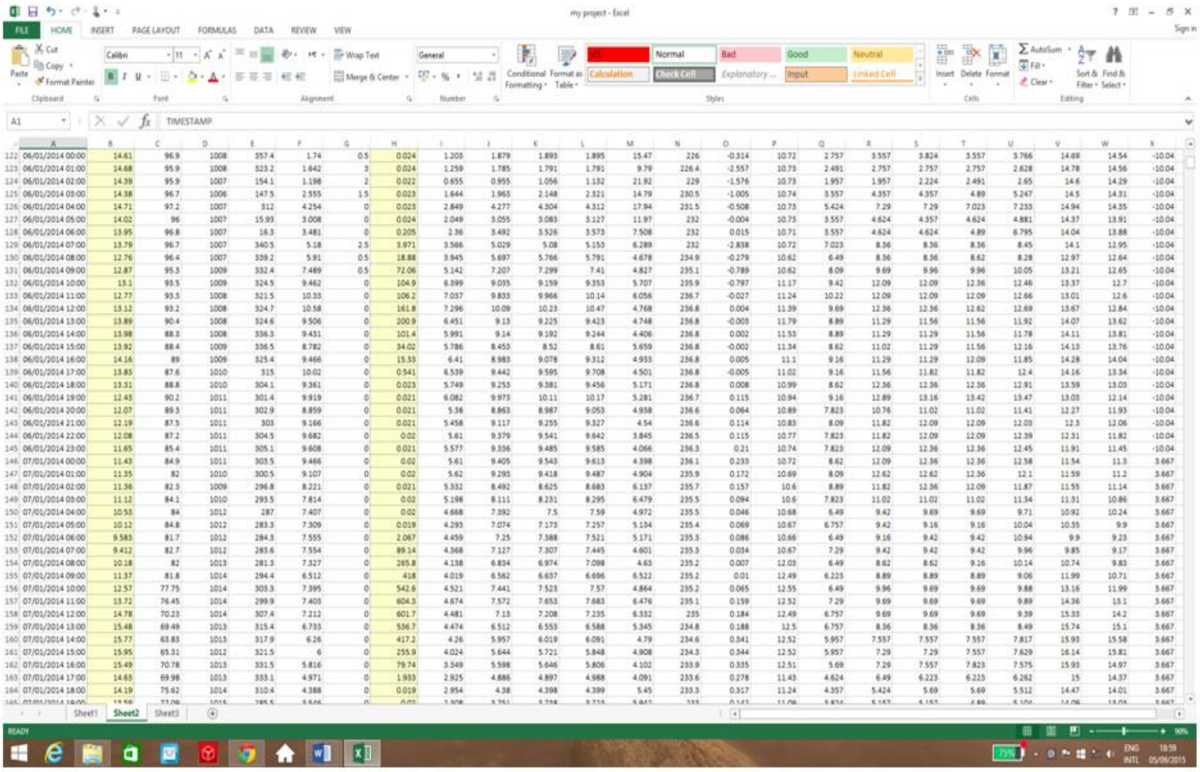
2006 ONWARDS

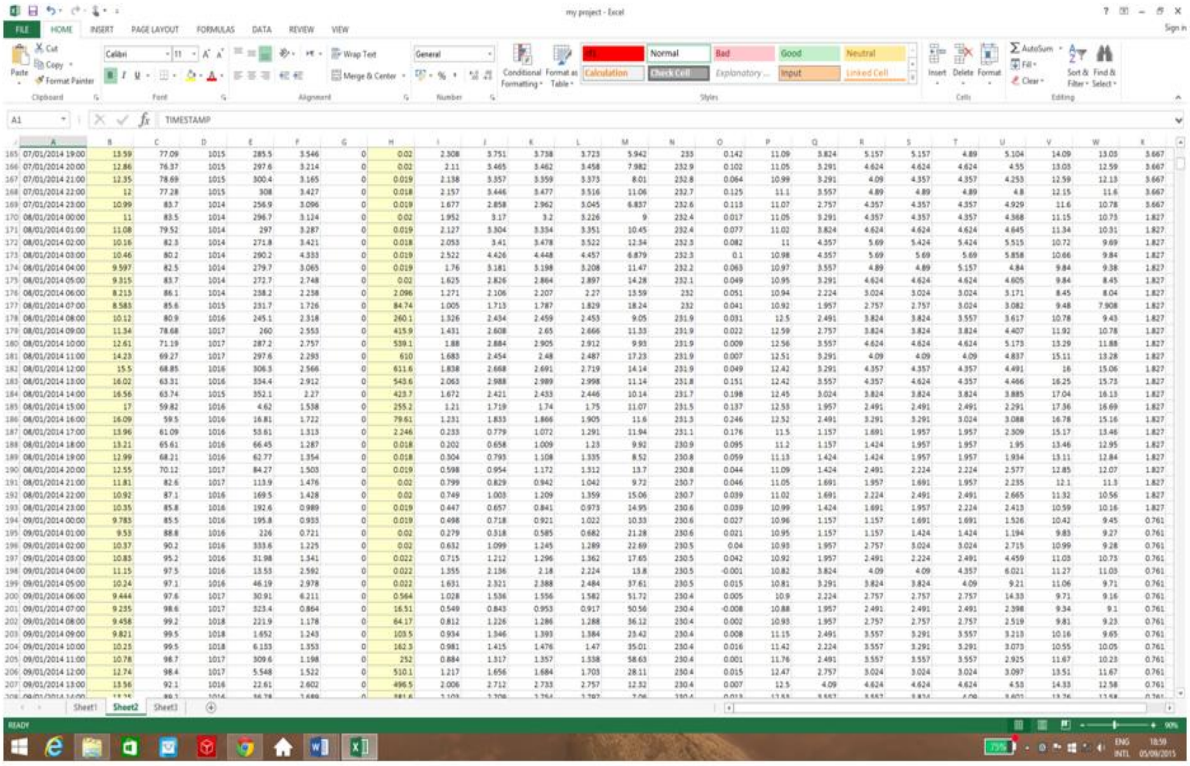
Parameters	Definition
AT	Atmospheric Temperature[^oC]
RH	Relative Humidity [%]
BP	Barometric Pressure [mbar]
WD1	Wind Direction [Degree]
WS1	Wind speed at 10m height [m/s]
RN	Rainfall [mm]
SR	Solar Radiation [W/m^2]
WS5	Wind speed at 1m height [m/s]
WS4	Wind speed at 4m height [m/s]
WS3	Wind speed at 6m height [m/s]
WS2	Wind speed at 8m height [m/s]
SG1	Sigma [Degree] S (Scalar) computes a scalar average, and is used for all measurements except Wind Direction and Rainfall. Sigma Theta (the standard deviation of Wind Direction) is computed as a scalar average as well. V (Vector) computes a vector average for Wind Direction as follows: $D = \arctan (D_y / D_x)$, where D = Vector Average Wind Direction $D_y = (\Sigma \sin D_i) / n$ $D_x = (\Sigma \cos D_i) / n$ D_i = Instantaneous Wind Direction measurement And n = number of samples.
EVlev	Evaporation level [mm]
EVdif	Evaporation difference [mm]
BATT	Battery voltage [Volt]
WS5gst	Wind speed gust at 1m height, which is the maximum wind speed in every 3 seconds [m/s]
WS4gst	Wind speed gust at 4m height , which is the maximum wind speed in every 3 seconds [m/s]
WS3gst	Wind speed gust at 6m height, which is the maximum wind speed in every 3 seconds [m/s]
WS2gst	Wind speed gust at 8m height, which is the maximum wind speed in every 3 seconds [m/s]
WS1gst	Wind speed gust at 10m height , which is the maximum wind speed in every 3 seconds [m/s]
ATmx	Atmospheric Temperature maximum [^oC]
ATmn	Atmospheric Temperature minimum [^oC]
EVdtot	Evaporation difference total [mm]

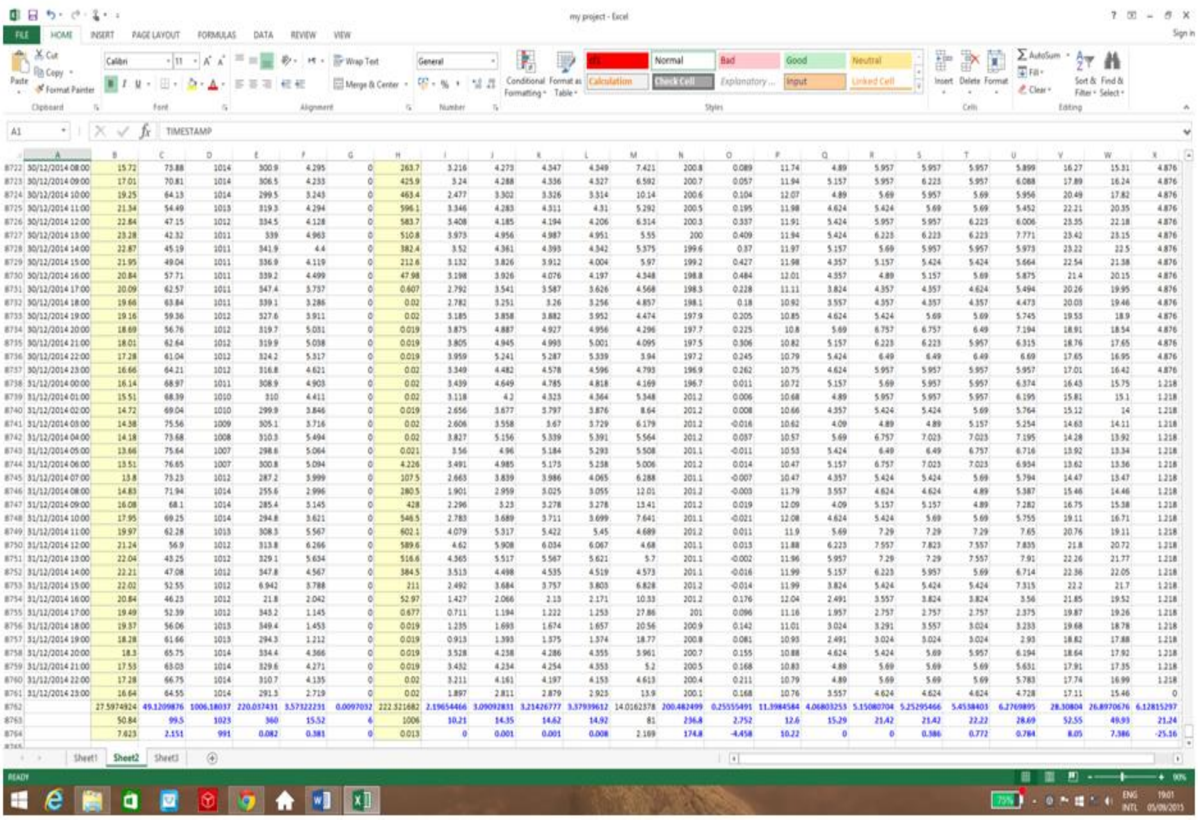


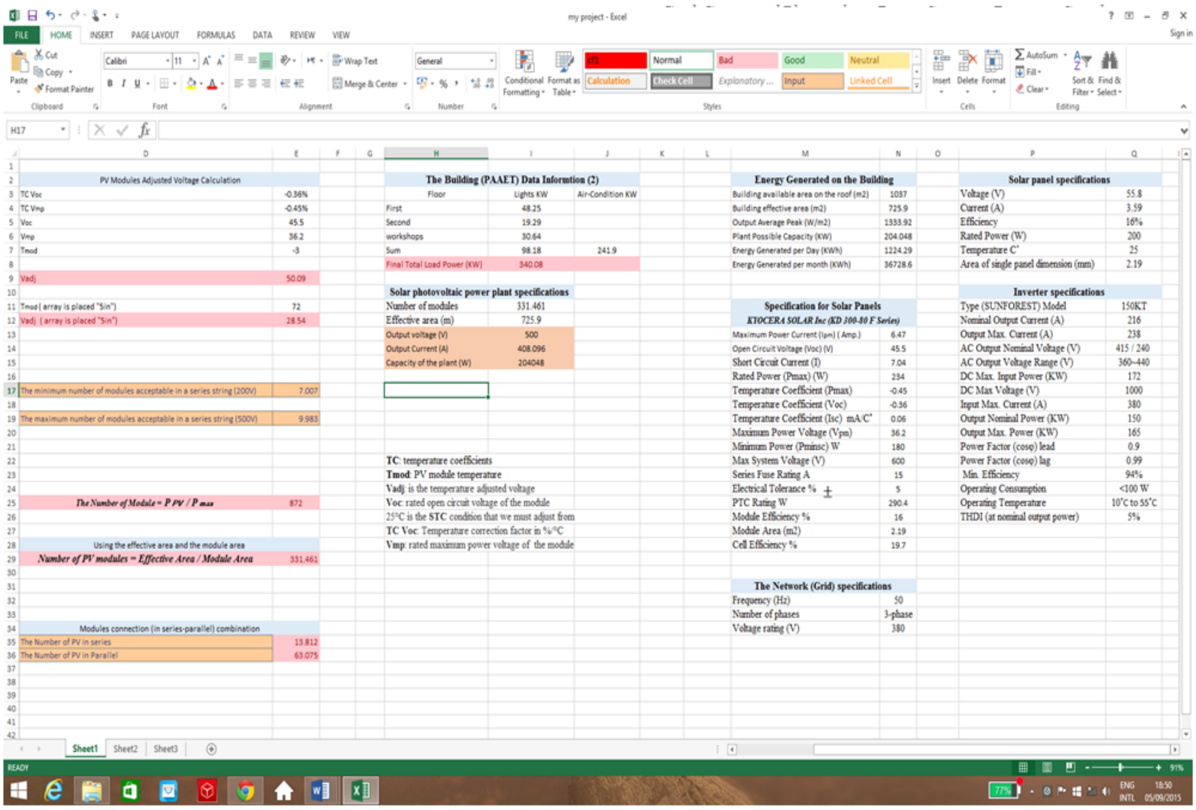


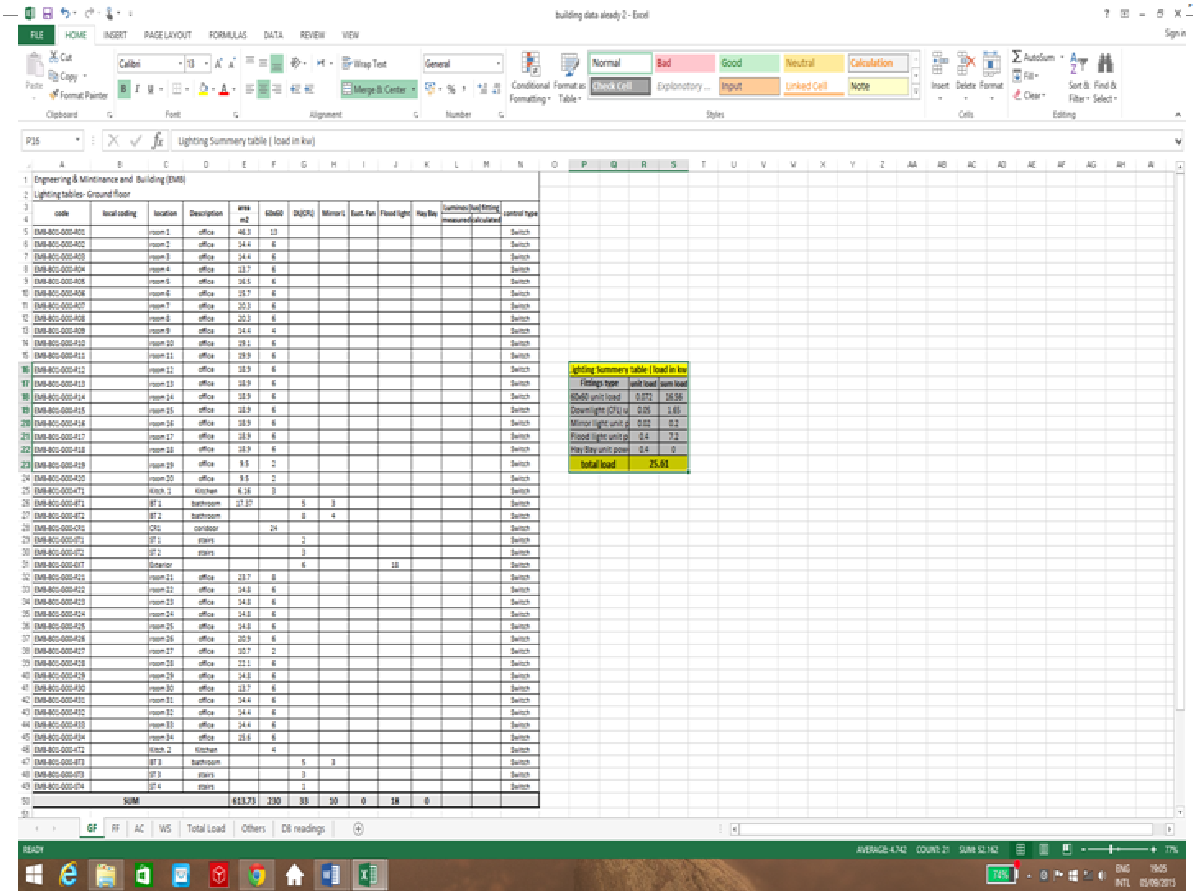

my project - Excel
Sheet1 Sheet2 Sheet3

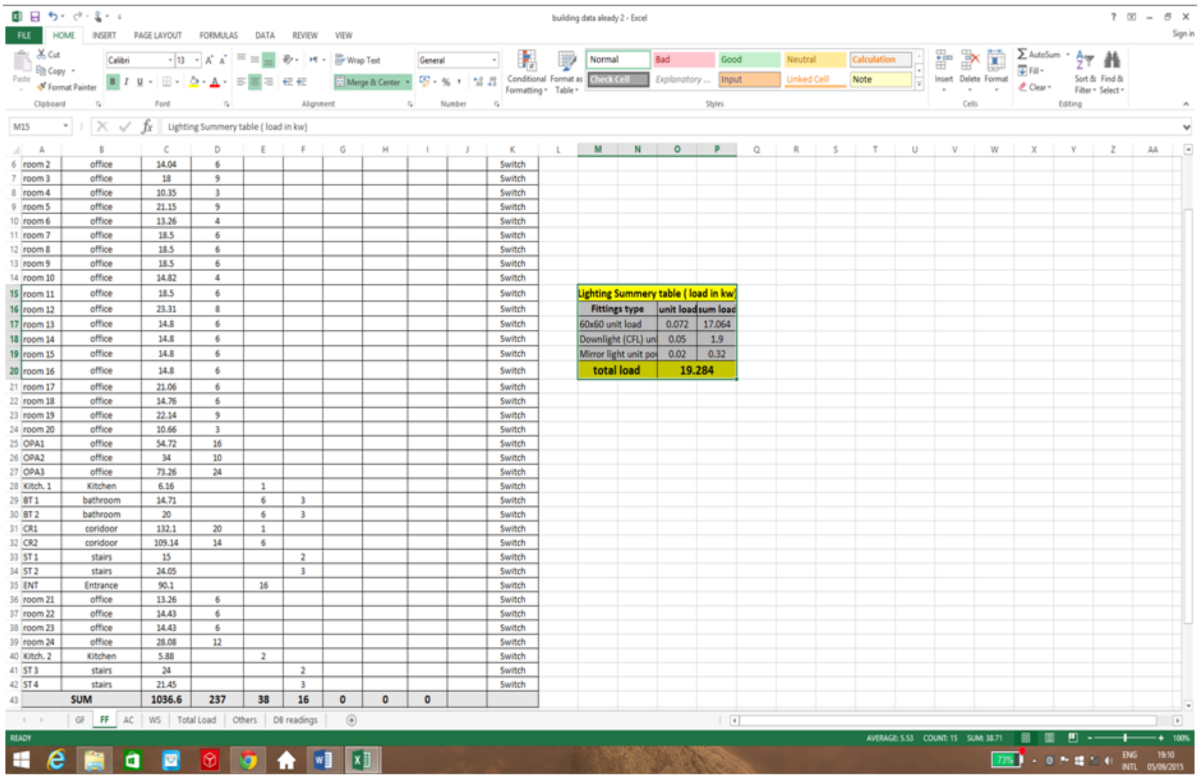

my project - Excel
Sheet1 Sheet2 Sheet3





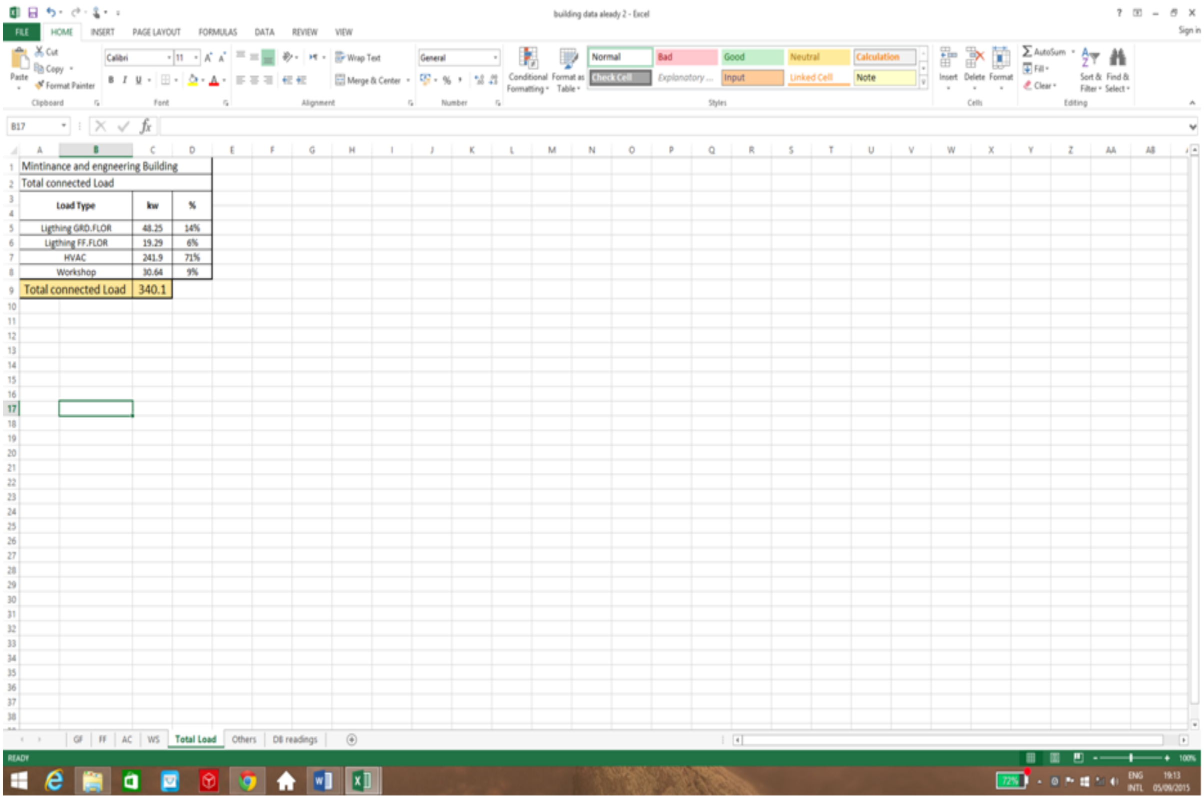

my project - Excel
PV Modules Adjusted Voltage Calculation
TC Voc -0.36%
TC Vmp -0.45%
Voc 45.5
Vmp 36.2
Tmod -3
Vadj 50.09
Tmod (array is placed "Sin") 72
Vadj (array is placed "Sin") 28.54
The minimum number of modules acceptable in a series string (200V) 7.007
The maximum number of modules acceptable in a series string (500V) 9.983
The Number of Module = P PV / P max 872
Using the effective area and the module area
Number of PV modules = Effective Area / Module Area 331.461
Modules connection (in series-parallel) combination
The Number of PV in series 13.812
The Number of PV in Parallel 63.075
The Building (PAAET) Data Informtion (2)
Floor | Lights KW | Air-Condition KW
First 48.25
Second 19.29
workshops 30.64
Sum 98.18 241.9
Final Total Load Power (KW) 340.08
Solar photovoltaic power plant specifications
Number of modules 331.461
Effective area (m) 725.9
Output voltage (V) 500
Output Current (A) 408.096
Capacity of the plant (W) 204048
TC: temperature coefficients
Tmod: PV module temperature
Vadj: is the temperature adjusted voltage
Voc: rated open circuit voltage of the module
25°C is the STC condition that we must adjust from
TC Voc: Temperature correction factor in %/°C
Vmp: rated maximum power voltage of the module
Energy Generated on the Building
Building available area on the roof (m2) 1037
Building effective area (m2) 725.9
Output Average Peak (W/m2) 1333.92
Plant Possible Capacity (KW) 204.048
Energy Generated per Day (KWh) 1224.29
Energy Generated per month (KWh) 36728.6
Specification for Solar Panels
KTOCERA SOLAR Inc (KD 300-80 F Series)
Maximum Power Current (Ipm) (Amp.) 6.47
Open Circuit Voltage (Voc) (V) 45.5
Short Circuit Current (I) 7.04
Rated Power (Pmax) (W) 234
Temperature Coefficient (Pmax) -0.45
Temperature Coefficient (Voc) -0.36
Temperature Coefficient (Isc) mA/C° 0.06
Maximum Power Voltage (Vpm) 36.2
Minimum Power (Pminsc) W 180
Max System Voltage (V) 600
Series Fuse Rating A 15
Electrical Tolerance % ± 5
PTC Rating W 290.4
Module Efficiency % 16
Module Area (m2) 2.19
Cell Efficiency % 19.7
The Network (Grid) specifications
Frequency (Hz) 50
Number of phases 3-phase
Voltage rating (V) 380
Solar panel specifications
Voltage (V) 55.8
Current (A) 3.59
Efficiency 16%
Rated Power (W) 200
Temperature C° 25
Area of single panel dimension (mm) 2.19
Inverter specifications
Type (SUNFOREST) Model 150KT
Nominal Output Current (A) 216
Output Max. Current (A) 238
AC Output Nominal Voltage (V) 415 / 240
AC Output Voltage Range (V) 360~440
DC Max. Input Power (KW) 172
DC Max Voltage (V) 1000
Input Max. Current (A) 380
Output Nominal Power (KW) 150
Output Max. Power (KW) 165
Power Factor (cosφ) lead 0.9
Power Factor (cosφ) lag 0.99
Min. Efficiency 94%
Operating Consumption <100 W
Operating Temperature 10°C to 55°C
THDI (at nominal output power) 5%
Sheet1 Sheet2 Sheet3


building data aleady 2 - Excel
Lighting Summery table (load in kw)
Engineering & Mintinance and Building (EMB)
Lighting tables- Ground floor
total load
25.61
SUM
GF FF AC WS Total Load Others DB readings

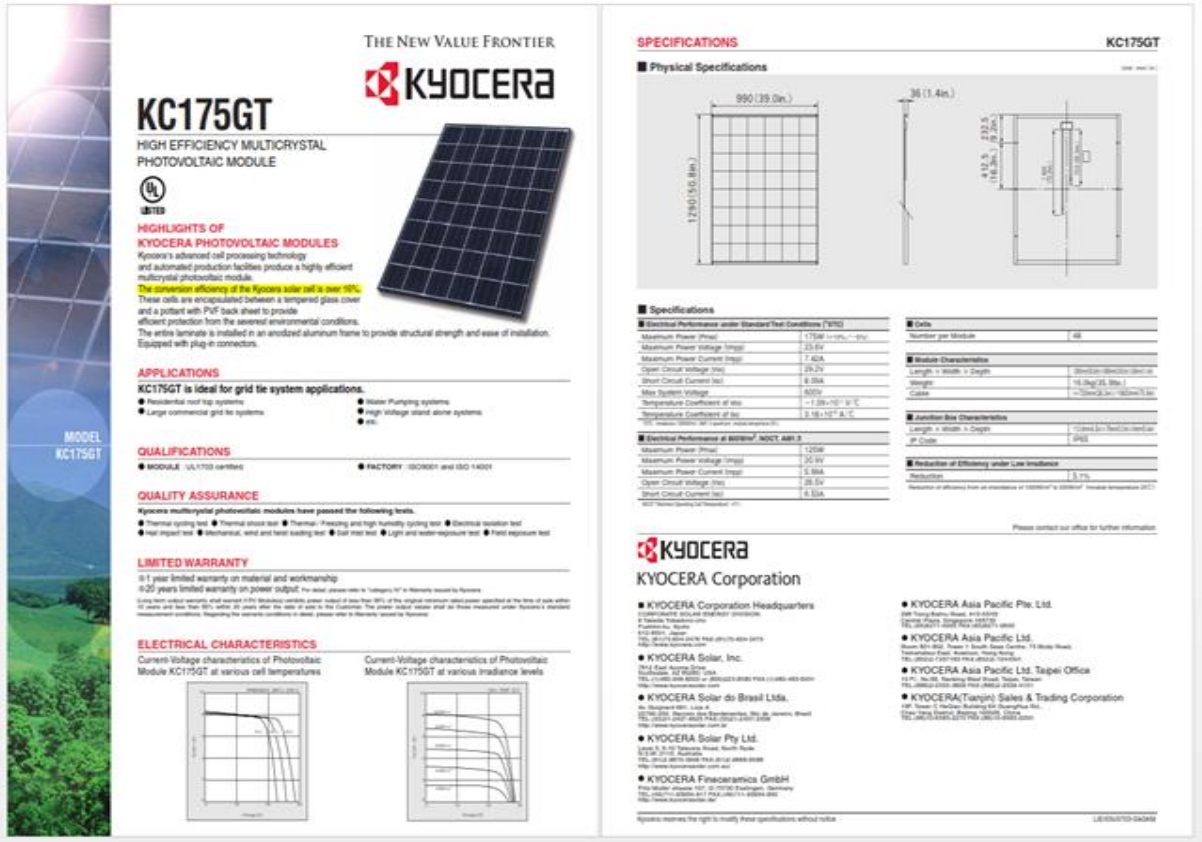


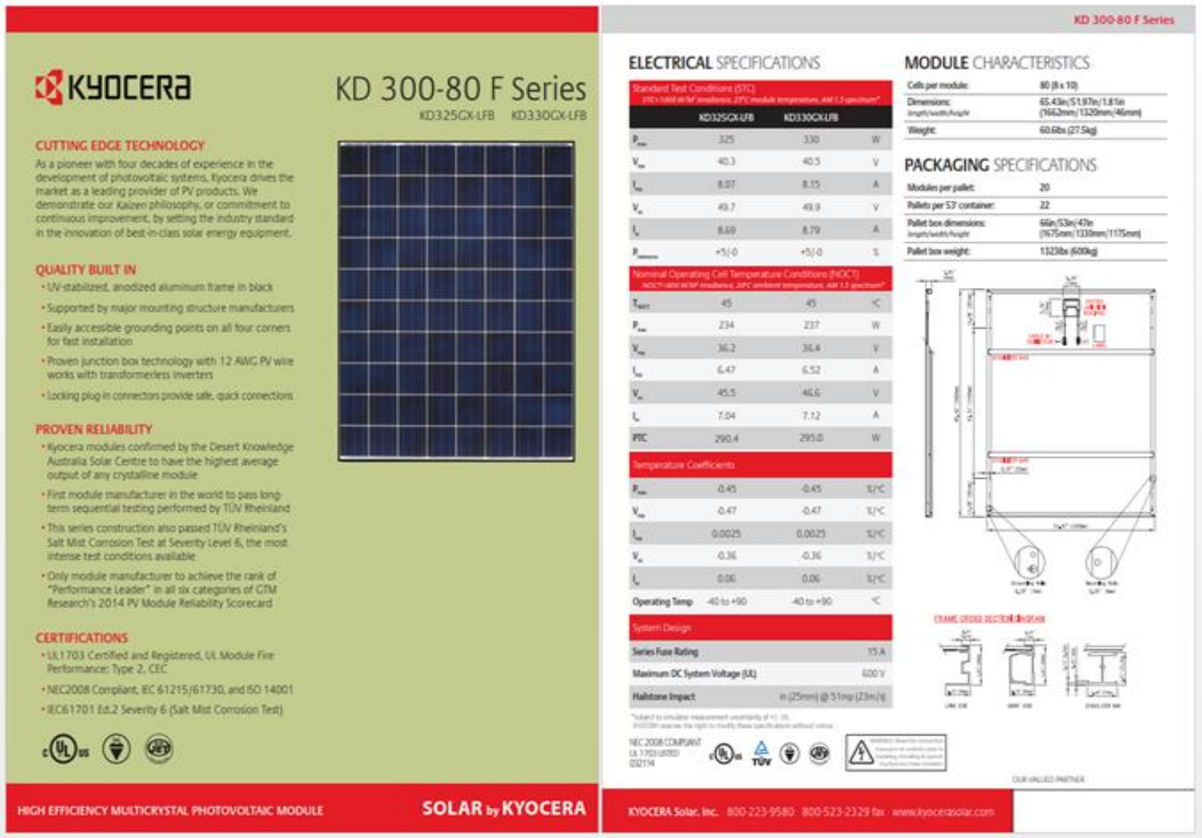
room 2	office	14.04	6						Switch
room 3	office	18	9						Switch
room 4	office	10.35	3						Switch
room 5	office	21.15	9						Switch
room 6	office	13.26	4						Switch
room 7	office	18.5	6						Switch
room 8	office	18.5	6						Switch
room 9	office	18.5	6						Switch
room 10	office	14.82	4						Switch
room 11	office	18.5	6						Switch
room 12	office	23.31	8						Switch
room 13	office	14.8	6						Switch
room 14	office	14.8	6						Switch
room 15	office	14.8	6						Switch
room 16	office	14.8	6						Switch
room 17	office	21.06	6						Switch
room 18	office	14.76	6						Switch
room 19	office	22.14	9						Switch
room 20	office	10.66	3						Switch
OPA1	office	54.72	16						Switch
OPA2	office	34	10						Switch
OPA3	office	73.26	24						Switch
Kitch. 1	Kitchen	6.16		1					Switch
BT 1	bathroom	14.71		6	3				Switch
BT 2	bathroom	20		6	3				Switch
CR1	coridoor	132.1	20	1					Switch
CR2	coridoor	109.14	14	6					Switch
ST 1	stairs	15			2				Switch
ST 2	stairs	24.05			3				Switch
ENT	Entrance	90.1		16					Switch
room 21	office	13.26	6						Switch
room 22	office	14.43	6						Switch
room 23	office	14.43	6						Switch
room 24	office	28.08	12						Switch
Kitch. 2	Kitchen	5.88		2					Switch
ST 3	stairs	24			2				Switch
ST 4	stairs	21.45			3				Switch
SUM		**1036.6**	**237**	**38**	**16**	**0**	**0**	**0**	

Lighting Summery table (load in kw)		
Fittings type	**unit load**	**sum load**
60x60 unit load	0.072	17.064
Downlight (CFL) uni	0.05	1.9
Mirror light unit po	0.02	0.32
total load	**19.284**	



Mintinance and engneering Building		
Total connected Load		
Load Type	**kw**	**%**
Ligthing GRD.FLOR	48.25	14%
Ligthing FF.FLOR	19.29	6%
HVAC	241.9	71%
Workshop	30.64	9%
Total connected Load	340.1	


THE NEW VALUE FRONTIER
KYOCERA
KC175GT
HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE
HIGHLIGHTS OF KYOCERA PHOTOVOLTAIC MODULES
APPLICATIONS
KC175GT is ideal for grid tie system applications.
QUALIFICATIONS
QUALITY ASSURANCE
LIMITED WARRANTY
ELECTRICAL CHARACTERISTICS
Current-Voltage characteristics of Photovoltaic Module KC175GT at various cell temperatures
Current-Voltage characteristics of Photovoltaic Module KC175GT at various irradiance levels
MODEL KC175GT
SPECIFICATIONS
KC175GT
Physical Specifications
990 (39.0in.)
1290 (50.8in.)
36 (1.4in.)
Specifications
Cells
Number per Module
48
Module Characteristics
Junction Box Characteristics
Reduction of Efficiency under Low Irradiance
KYOCERA
KYOCERA Corporation
KYOCERA Corporation Headquarters
KYOCERA Solar, Inc.
KYOCERA Solar do Brasil Ltda.
KYOCERA Solar Pty Ltd.
KYOCERA Fineceramics GmbH
KYOCERA Asia Pacific Pte. Ltd.
KYOCERA Asia Pacific Ltd.
KYOCERA Asia Pacific Ltd. Taipei Office
KYOCERA(Tianjin) Sales & Trading Corporation


KYOCERA
KD 300-80 F Series
KD325GX-LFB KD330GX-LFB
CUTTING EDGE TECHNOLOGY
As a pioneer with four decades of experience in the development of photovoltaic systems, Kyocera drives the market as a leading provider of PV products. We demonstrate our Kaizen philosophy, or commitment to continuous improvement, by setting the industry standard in the innovation of best-in-class solar energy equipment.
QUALITY BUILT IN
• UV-stabilized, anodized aluminum frame in black
• Supported by major mounting structure manufacturers
• Easily accessible grounding points on all four corners for fast installation
• Proven junction box technology with 12 AWG PV wire works with transformerless inverters
• Locking plug-in connectors provide safe, quick connections
PROVEN RELIABILITY
• Kyocera modules confirmed by the Desert Knowledge Australia Solar Centre to have the highest average output of any crystalline module
• First module manufacturer in the world to pass long-term sequential testing performed by TÜV Rheinland
• This series construction also passed TÜV Rheinland's Salt Mist Corrosion Test at Severity Level 6, the most intense test conditions available
• Only module manufacturer to achieve the rank of "Performance Leader" in all six categories of GTM Research's 2014 PV Module Reliability Scorecard
CERTIFICATIONS
• UL1703 Certified and Registered, UL Module Fire Performance: Type 2, CEC
• NEC2008 Compliant, IEC 61215/61730, and ISO 14001
• IEC61701 Ed.2 Severity 6 (Salt Mist Corrosion Test)
HIGH EFFICIENCY MULTICRYSTAL PHOTOVOLTAIC MODULE
SOLAR by KYOCERA
KD 300-80 F Series
ELECTRICAL SPECIFICATIONS
Standard Test Conditions (STC)
KD325GX-LFB KD330GX-LFB
P 325 330 W
V 40.3 40.5 V
I 8.07 8.15 A
V 49.7 49.9 V
I 8.69 8.79 A
P +5/-0 +5/-0 %
Nominal Operating Cell Temperature Conditions (NOCT)
T 45 45 °C
P 234 237 W
V 36.2 36.4 V
I 6.47 6.52 A
V 45.5 46.6 V
I 7.04 7.12 A
PTC 290.4 295.0 W
Temperature Coefficients
P -0.45 -0.45 %/°C
V -0.47 -0.47 %/°C
I 0.0025 0.0025 %/°C
V -0.36 -0.36 %/°C
I 0.06 0.06 %/°C
Operating Temp -40 to +90 -40 to +90 °C
System Design
Series Fuse Rating 15 A
Maximum DC System Voltage (UL) 600 V
Hailstone Impact in (25mm) @ 51mp (23m/s)
NEC 2008 COMPLIANT
UL 1703 LISTED
032114
MODULE CHARACTERISTICS
Cells per module: 80 (8 x 10)
Dimensions: length/width/height 65.43in/51.97in/1.81in (1662mm/1320mm/46mm)
Weight: 60.6lbs (27.5kg)
PACKAGING SPECIFICATIONS
Modules per pallet: 20
Pallets per 53' container: 22
Pallet box dimensions: length/width/height 66in/53in/47in (1675mm/1330mm/1175mm)
Pallet box weight: 1323lbs (600kg)
FRAME CROSS SECTION DIAGRAM
OUR VALUED PARTNER
KYOCERA Solar, Inc. 800-223-9580 800-523-2329 fax www.kyocerasolar.com

PV Inverters

PowerGate Plus 210 kW S-Type UL

PVS-210-S-UL

Satcon PowerGate Plus PV inverters are the world's most widely deployed solutions, powering many of the largest commercial and utility-scale solar installations.

Advanced Performance

Utility-Ready Features

EDGE MPPT

Printed Circuit Board Durability

Profitable PV Power

The Satcon® PowerGate® Plus 210 kW S-Type PV inverters have a significant impact on the profitability dynamic of large-scale solar PV systems. With its system intelligence, next-generation EDGE® MPPT technology and industrial-grade engineering, the PowerGate Plus 210 kW S-Type inverters maximize system uptime and power production, even in the harshest environments.

Advanced, Rugged, and Reliable

Engineered from the ground up to meet the demands of large-scale installations, Satcon PV inverters feature an outdoor-rated enclosure, advanced monitoring and control capabilities and EDGE, Satcon's next-generation MPPT solution.

Proven Performance

The proven leader in solar PV inverter solutions for commercial installations, Satcon sets the standards for efficient large-scale power conversion.

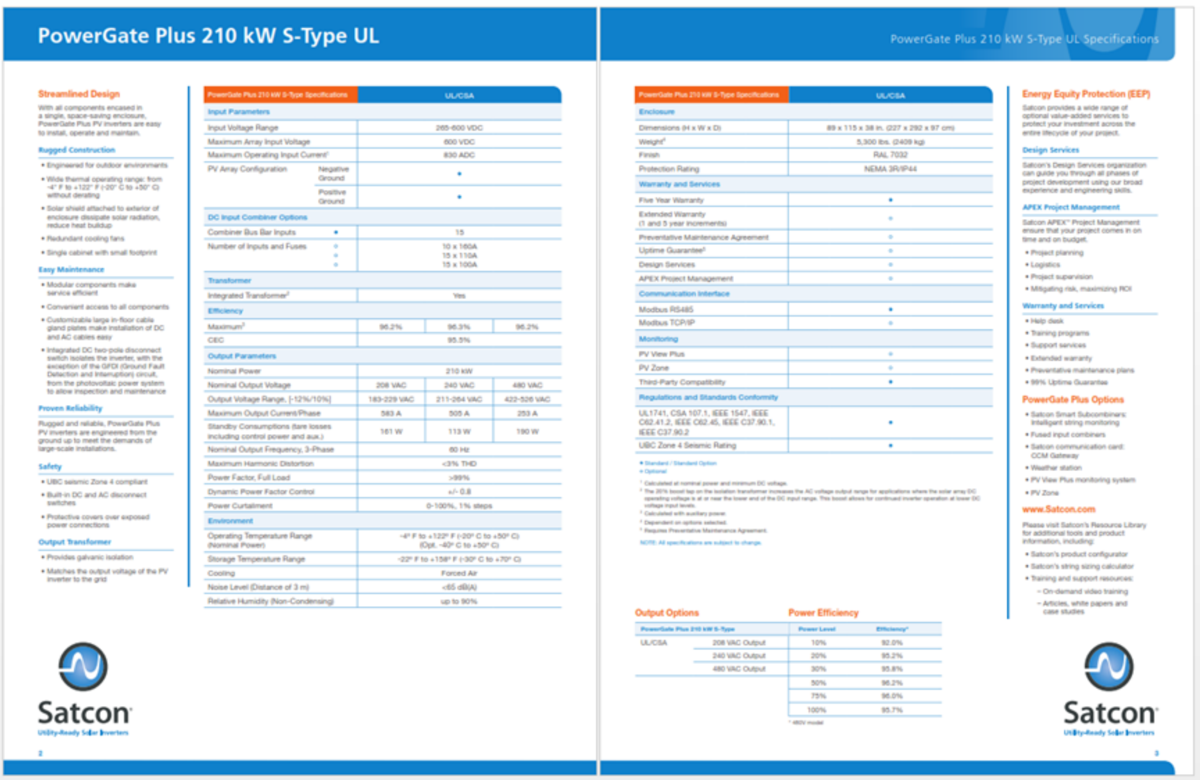
Increased PV Plant Yield

At the heart of PowerGate Plus is EDGE, Satcon's next-generation power optimization solution. With rapid and accurate MPPT control, EDGE increases PV plant kWh yield by extending the production window of arrays, enabling them to operate at optimal voltage and current levels for longer periods of time—even in varied sun conditions. To maximize efficiency, EDGE improves the performance of all PV technologies, including fixed and tracking solar arrays, enabling you to get the most from your investment.

Satcon

www.Satcon.com
www.cecgwenergy.com

Satcon



PowerGate Plus 210 kW S-Type UL

Streamlined Design

With all components encased in a single, space-saving enclosure, PowerGate Plus PV inverters are easy to install, operate and maintain.

Rugged Construction

- Engineered for outdoor environments
- Wide thermal operating range: from -4° F to +122° F (-20° C to +50° C) without derating
- Solar shield attached to exterior of enclosure dissipate solar radiation, reduce heat buildup
- Redundant cooling fans
- Single cabinet with small footprint

Easy Maintenance

- Modular components make service efficient
- Convenient access to all components
- Customizable large in-floor cable gland plates make installation of DC and AC cables easy
- Integrated DC two-pole disconnect switch isolates the inverter, with the exception of the GFDI (Ground Fault Detection and Interruption) circuit, from the photovoltaic power system to allow inspection and maintenance

Proven Reliability

Rugged and reliable, PowerGate Plus PV inverters are engineered from the ground up to meet the demands of large-scale installations.

Safety

- UBC seismic Zone 4 compliant
- Built-in DC and AC disconnect switches
- Protective covers over exposed power connections

Output Transformer

- Provides galvanic isolation
- Matches the output voltage of the PV inverter to the grid

PowerGate Plus 210 kW S-Type Specifications		UL/CSA		
Input Parameters				
Input Voltage Range		265-600 VDC		
Maximum Array Input Voltage		600 VDC		
Maximum Operating Input Current[1]		830 ADC		
PV Array Configuration	Negative Ground	•		
	Positive Ground	•		
DC Input Combiner Options				
Combiner Bus Bar Inputs	•	15		
Number of Inputs and Fuses	◦ ◦ ◦	10 x 160A 15 x 110A 15 x 100A		
Transformer				
Integrated Transformer[2]		Yes		
Efficiency				
Maximum[3]		96.2%	96.3%	96.2%
CEC		95.5%		
Output Parameters				
Nominal Power		210 kW		
Nominal Output Voltage		208 VAC	240 VAC	480 VAC
Output Voltage Range, [-12%/10%]		183-229 VAC	211-264 VAC	422-528 VAC
Maximum Output Current/Phase		583 A	505 A	253 A
Standby Consumptions (tare losses including control power and aux.)		161 W	113 W	190 W
Nominal Output Frequency, 3-Phase		60 Hz		
Maximum Harmonic Distortion		<3% THD		
Power Factor, Full Load		>99%		
Dynamic Power Factor Control		+/- 0.8		
Power Curtailment		0-100%, 1% steps		
Environment				
Operating Temperature Range (Nominal Power)		-4° F to +122° F (-20° C to +50° C) (Opt. -40° C to +50° C)		
Storage Temperature Range		-22° F to +158° F (-30° C to +70° C)		
Cooling		Forced Air		
Noise Level (Distance of 3 m)		<65 dB(A)		
Relative Humidity (Non-Condensing)		up to 90%		

Satcon

PowerGate Plus 210 kW S-Type UL Specifications

PowerGate Plus 210 kW S-Type Specifications	UL/CSA
Enclosure	
Dimensions (H x W x D)	89 x 115 x 38 in. (227 x 292 x 97 cm)
Weight[4]	5,300 lbs. (2409 kg)
Finish	RAL 7032
Protection Rating	NEMA 3R/IP44
Warranty and Services	
Five Year Warranty	•
Extended Warranty (1 and 5 year increments)	◦
Preventative Maintenance Agreement	◦
Uptime Guarantee[5]	◦
Design Services	◦
APEX Project Management	◦
Communication Interface	
Modbus RS485	•
Modbus TCP/IP	◦
Monitoring	
PV View Plus	◦
PV Zone	◦
Third-Party Compatibility	•
Regulations and Standards Conformity	
UL1741, CSA 107.1, IEEE 1547, IEEE C62.41.2, IEEE C62.45, IEEE C37.90.1, IEEE C37.90.2	•
UBC Zone 4 Seismic Rating	•

• Standard / Standard Option
◦ Optional

[1] Calculated at nominal power and minimum DC voltage.
[2] The 20% boost tap on the isolation transformer increases the AC voltage output range for applications where the solar array DC operating voltage is at or near the lower end of the DC input range. This boost allows for continued inverter operation at lower DC voltage input levels.
[3] Calculated with auxiliary power.
[4] Dependent on options selected.
[5] Requires Preventative Maintenance Agreement.

NOTE: All specifications are subject to change.

Output Options

PowerGate Plus 210 kW S-Type	
UL/CSA	208 VAC Output
	240 VAC Output
	480 VAC Output

Power Efficiency

Power Level	Efficiency*
10%	92.0%
20%	95.2%
30%	95.8%
50%	96.2%
75%	96.0%
100%	95.7%

* 480V model

Energy Equity Protection (EEP)

Satcon provides a wide range of optional value-added services to protect your investment across the entire lifecycle of your project.

Design Services

Satcon's Design Services organization can guide you through all phases of project development using our broad experience and engineering skills.

APEX Project Management

Satcon APEX™ Project Management ensure that your project comes in on time and on budget.

- Project planning
- Logistics
- Project supervision
- Mitigating risk, maximizing ROI

Warranty and Services

- Help desk
- Training programs
- Support services
- Extended warranty
- Preventative maintenance plans
- 99% Uptime Guarantee

PowerGate Plus Options

- Satcon Smart Subcombiners: Intelligent string monitoring
- Fused input combiners
- Satcon communication card: CCM Gateway
- Weather station
- PV View Plus monitoring system
- PV Zone

www.Satcon.com

Please visit Satcon's Resource Library for additional tools and product information, including:

- Satcon's product configurator
- Satcon's string sizing calculator
- Training and support resources:
  - On-demand video training
  - Articles, white papers and case studies

Satcon