The International Journal Of Engineering And Science (IJES)
|| Volume || 5 || Issue || 3 || Pages || PP -94-105|| 2016 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Promising Photovoltaic Power Systems (PV)

Adel Ali Alsaad* Humoud A AL.qattan**

ABSTRACT

The sources of renewable energy provides a potentially promising and far less harmful alternative to traditional methods of electricity production. Grid-connected Photovoltaic (PV) systems are a promising tool to provide electric power to houses and other buildings. Solar radiation is an important factor for the production of electricity by PV systems. There are various technical advantages for Grid-connected PV systems in places where the solar radiation is abundant. The advantages include the easy, simple and flexible installation of the system.

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 thesecan 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 KW after crossing the atmosphere during the daytime hours.Photovoltaic solar energy can highlylikely be used domestically in sun shine countries such as middle eastregions, 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.

There are various technical advantages for Grid-connected PV systems in places where the solar radiation is abundant. The advantages include the easy, simple and flexible installation of the system. Furthermore, it would require little maintenance in such places [5], [6].

Customers in many countries are being encouraged to generate energy domestically using PV systems, which would help to reduce their bills. This also allows renewable energy sources to contribute more in this domain and this would finally result in reducing emissions of carbon dioxide (CO2). Basically, 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 is 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 knownas 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].

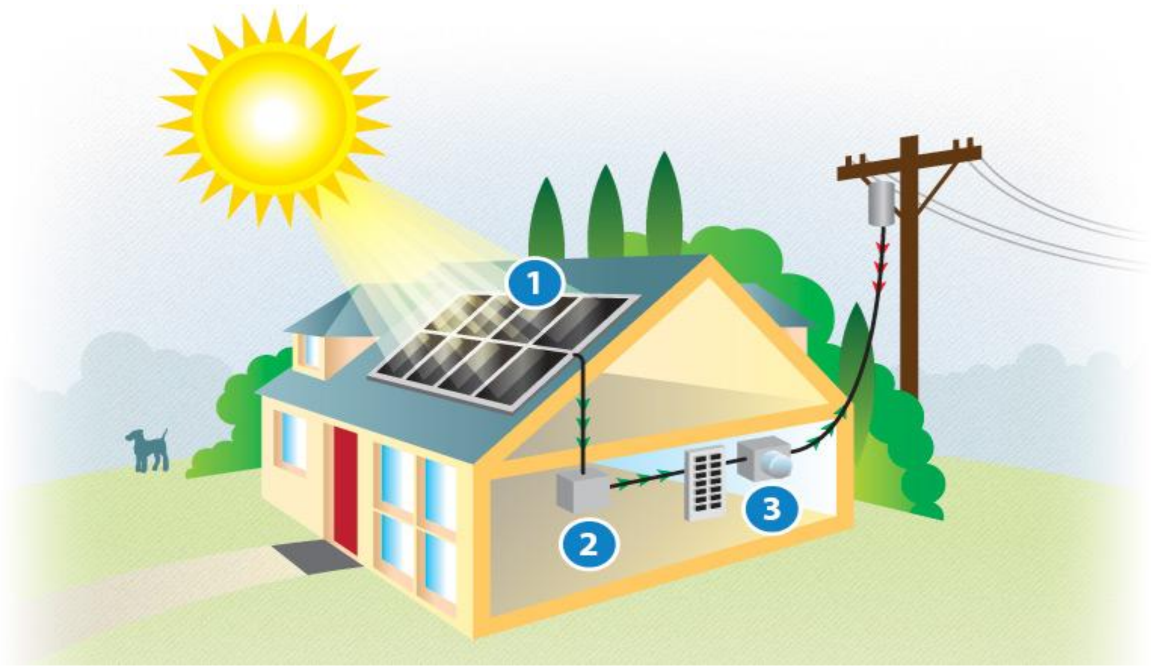


Figure1: Proposed direct grid-connected PV System [14]

This paper provides an introduction and analysis of a grid-connected photovoltaic power system that can be usedas basic information for domestically used in houses. Moreover, the impact of temperature and irradiance on PVwill be explained.

II. Literature Review

2.1 Photovoltaic System Calculation Highs and Lows:

Since voltage power inputs of the component electronics involved in a PV system, such as grid-direct inverters, have a maximum and minimum degrees, it is important to adjust the voltage values of the module to satisfy the specific project needs. This step allows for ensuring that the system will operate properly. However, before calculating any voltage correction, understanding the PV modules basic voltage and current output and their variation with temperature changes and the intensity of the sun is essential.

Figure2: Modules of a PV system [15]

The two voltage values by which the PV modules are rated in open circuit voltage and maximum power voltage. While the open circuit voltage (Voc) is the available voltage at the state when neither current nor load connection exists in the module, the maximum power voltage (Mpv) is defined as the module maximum production of power.

As can be seen in figure 3 below, the yellow line, which depicts the current vs. the voltage, shows the open circuit voltage (Voc) occurring at the curve bottom side. In this case, it is illustrated that while the value of the current is zero, the value of the voltage is at its maximum level. Directly below the curve knee, the maximum power voltage (Vmp) appears. In Photovoltaic modules, it is always the case that the value of the (Voc) is higher than that of the (Vmp). The blue line illustrates the power versus voltage and this is usually provided by the manufacturers of the module in the same graph.

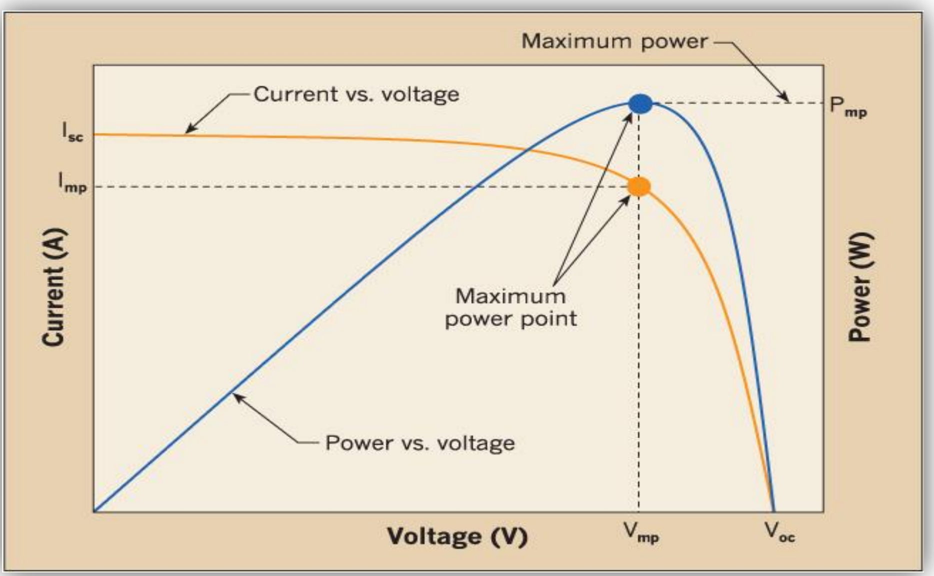


Figure 1: A typical current versus voltage curve in PV modules illustrating the relation between different factors at a state when temperature and irradiance levels are defined. The graph also presents the module power vs. voltage. [16]

Calculating the maximum power value in watts can be possible through multiplying two values with each other. These are the Vmp and the Imp. While the former value can be obtained from the intersection of a direct line drawn downward from the IV curve knee, the later value can be obtained from the intersection of a direct line drawn from the left-hand side of the knee.When the positive and negative units in the PV module become at a contacting point, short circuit current (I_{sc}) arises as is apparent in Figure 3 at the upper left corner.The PV module might not be damaged in such situation, but since in the module/s there is current that is flowing, caution is needed when the current flow is interrupted. The module might be damaged as a result of any incorrect disconnection which could lead to the appearance of a DC arc.

It is a listing requirement that the five values are listed by an attached label on the specification sheet of any PV module. Moreover, the listed values are in line with standard test conditions (STC). Irradiance [1,000 W/m^2] and temperature [25°C -77°F] are two important standard test conditions values for the values of the current and the voltage of the module.

The value of the temperature corresponds to that of the PV module and it is a function of the surrounding temperature, whereas the value of the irradiance can be linked to a day when the sun is bright at the level of the sea. Consequently, how these variations in the conditions of the environment could have an effect on the current and voltage is an important step that should be taken into account.

The volume of the PV module current production correlate positively with the level of sun brightness. The higher the level of irradiance is, the greater the amount of electrons that pass from the cells of the PV to the load attached to it. However, this value of the irradiance does not have as such impact on the PV module production of voltage.

It can be assumed that the full rated voltage of the PV module can be obtained if ambient light exists. In Figure 4, which depicts the typical IV curve of a module as a result of irradiance, it is illustrated that the voltage of the PV module does not change much with different irradiance levels. At irradiance levels of nearly 200 W/m^2, most of the rated voltage (about 90%) of the crystalline PV modules is yielded.

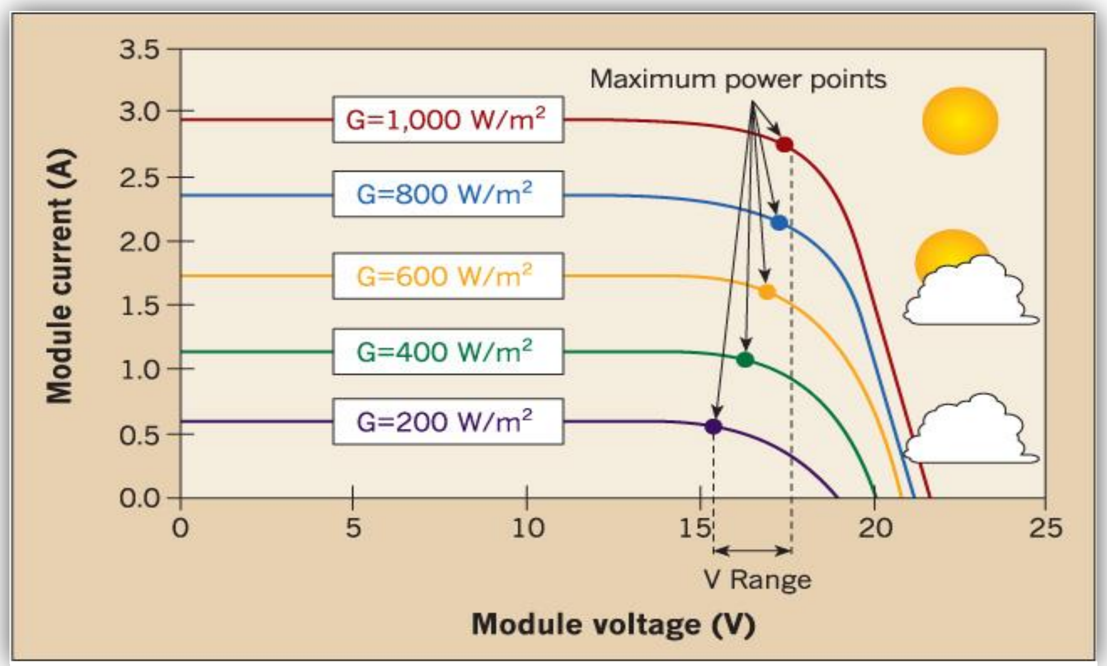


Figure4: Current versus voltage curve in a PV module varying in response to sunlight intensity or irradiance. I is clear that while dramatic changes in the current take place when the irradiance changes, a relatively stable level of voltage can be observed. [17]

The module voltage and its temperature correlate negatively with each other as that when the temperature rises the value of the voltage drops and when the temperature drops, the value of the voltage rises. Hence, the voltage output of the PV module is not stable, but variable because of the effect of the temperature. This negative correlation relationship is illustrated in Figure 5. This variability in the voltage output is essential in hot and cold temperatures. In the condition when the temperature is cold, the module voltage will rise and, adversely, in hot temperature conditions, the voltage value will decrease. In PV design, these cases cannot be avoided.

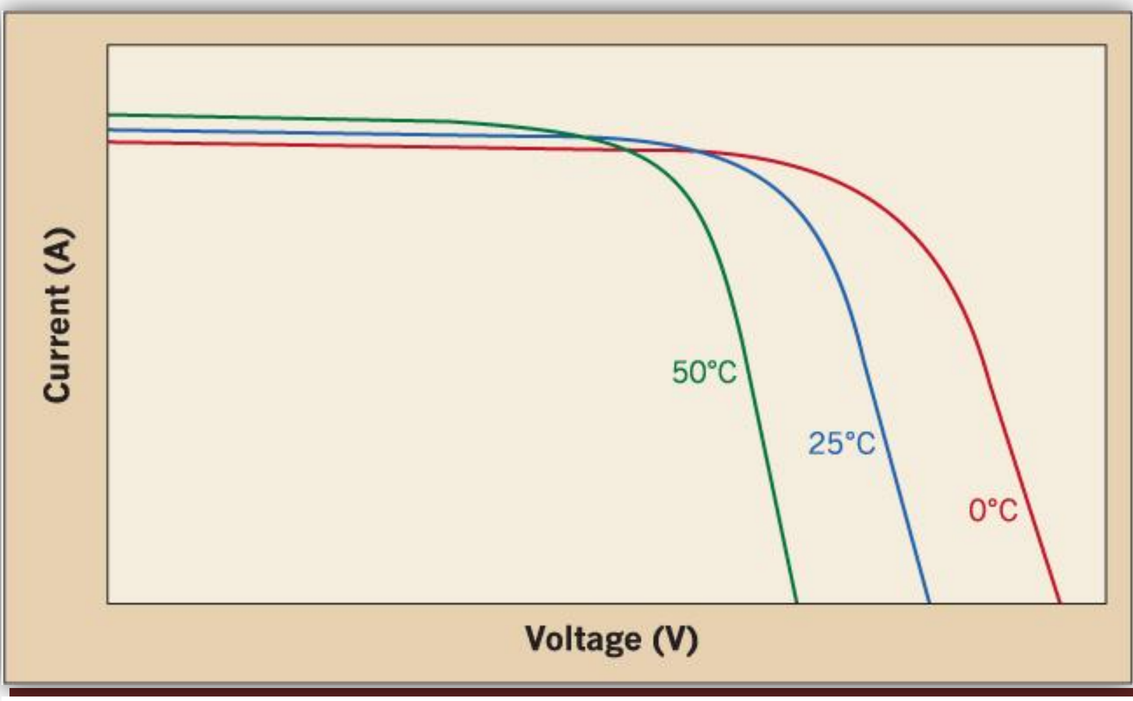


Figure 2: Voltage variability with the change of temperature. [18]

The amount of change in the module experience is often provided by PV module manufactures. This is usually reported as temperature coefficients (TCs) and this is given as a percentage per degree Celsius (e.g., TC Voc = -0.35%/°C). In other words, the Voc of the module will increase or decrease by 0.35% in the opposite direction to any rise or drop in the temperature. For instance, when the PV module becomes 1°C hotter, the voltage would decrease by 0.35%. Crystalline PV modules are known to have such value.

Moreover, two further points about the TC values should be mentioned. The first point is that there are two TCs for every PV module. These are for the Vmp and Voc, each of which experience a different change and they should be measured differently. The second point is that PV modules are rated at 25°C by the manufacturers. Therefore, when temperature coefficients are applied, finding out the number of Celsius degrees at which the PV module is operated from the STC value of 25°C.

PV modules will start their daily journey in the morning with a very little amount of sunlight. Since the PV arrays are kept outside in open air, the PV modules will have exactly the same temperature value as that of the ambient air at night. No immediate current will be produced by the modules because the array will not be exposed immediately to sunlight and, therefore, going to open circuit voltage will be the immediate condition. If the module temperature is lower than the STC value which is 25°C, the value of the Voc of the module will be higher than what is listed on the specification sheet of the module. For the purpose of the current project, the module temperature will be assumed to be the same as the ambient temperature. The new voltage value of the module will be estimated in the aim of verifying that not too many modules are placed in series, in which case their value would be greater than the maximum input value of the power electronics.
As soon as the sun rises up slightly reaching the array, enough irradiance will be available which will allow the flow of the current. Accordingly, the voltage value of the module will drop from the Voc point to a lower value nearer to the Vmp point. in the course of the day and with longer exposure to the sun, the module will receive more and more sunlight and thus the module temperature will continue to increase further. The temperature of the PV module will keep increasing based on the surrounding temperature and the closeness of the module to something that could aggregate heat like a rooftop. The following values can be used to calculate the PV module temperature in the middle of the afternoon:

- In the case that the module is not farther than 6in. from the roof surface: Tmod = Ambient + 35°C.
- In the case that the module is farther than 6in. from the roof surface: Tmod = Ambient + 30°C.
- In the case that the PV array is fixed on elevated ground or pole top: Tmod = Ambient + 25°C.

Many manufacturers use these values in assessing the voltage of the PV in different temperatures ad they are somewhat acceptable in this field. Through this method, it will be possible to confirm whether there are a sufficient number of modules that are positioned in series, which would ensure the operation of the power electronics during summer time.

The key question at this stage has become about the appropriate temperature to be used in the calculation. The temperature you are most comfortable with would be the answer. A method that is considered conservative and which is relied on in the calculation by some people is to record cold and high temperatures. Although this method might appear too conservative to some, it is unquestionably acceptable to many AHJs. However, using the data provided by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) is a more common method. 2% high temperature value and the lowest ambient temperature value are the two values looked for by most PV system designers. It is expected that the 2% high temperature corresponds to a value that would not be exceeded by more than 14 hours during a month in the summer season. An example in this case will lead to a better understanding for such a condition. Assume that the following temperature values, TCs and rated voltage values are available:

Table 1:

Data				
TC V_{OC}	TC V_{mp}	V_{OC}	V_{mp}	T_{mod}
-0.36%	-0.45%	45.5	36.2	-3

Table 2:

Characteristics of Modules		
Cells per module	Dimensions : *length/width/high*	Weight

80 (8*10)	(1662mm/1320mm/46mm)	27.5 kg

[Lowest temperature degree expected as reported on solarabcs.org: -3°C; 2% high temperature: 37°C].

The first step that needs to be done is calculating the adjusted Voc. The adjusting requirements for his module is provided in 2011 NEC Section 690.7. The Code states that this data can be used for calculating the adjusted voltage of the module for cold temperatures, if data about the temperature coefficient is provided by the manufacturer of the module. However, in case the data is not provided by the manufacturer and the module being used works on crystalline technology, estimating the adjusted voltage of the module can be performed using Table 690.7. Since the calculations provided by NEC are always conservative, running the actual calculations separately might be useful. Moreover, running the actual calculations will be needed if the technology being used is not crystalline because the values provided in the Table will not be applicable. The adjusted voltage of the module can be calculated by the following equation:

$$V_{adj} = V_{OC} \times \left[100\% + \left((T_{mod} - 25℃) \times TC\ V_{OC}\right)\right] \quad (1)$$

- $TC\ V_{OC}$ is Temperature correction factor in %/°C
- V_{adj} is the temperature adjusted voltage
- V_{OC} is rated open circuit voltage of the module
- T_{mod} is the temperature of the PV module
- 25°C is the STC condition that we must adjust from

The values provided in the table can be used to calculate the V_{adj} as follows:

$$\begin{aligned} V_{adj} &= 45.5 \times \left[100\% + \left((-3 - 25℃) \times -0.33\right)\right] \\ &= 45.5 \times \left[100\% + \left((-28℃) \times -0.33\right)\right] \\ &= 45.5 \times [100\% + 9.24\%] \\ &= 45.5 \times [109.24\%] = 49.7\ volt \end{aligned}$$

This shows that the Voc value of 49.7V (not 45.5V) should be applied in the process of taking a decision about the number of modules that can be positioned in series with certain types of inverters or other pieces of power electronics. A potential damage or injuries to people can be caused if too much voltage is placed on the equipment and this clarifies why this issue is related to NEC.

The second step that need to be done is calculating the value of the Vmp at high temperature. Since NEC does not provide a Table as in the case of the cold temperature, determining the value here requires conducting the calculation. The same formula that is used with cold temperature can be used here, but with different values given to each of the variables.

The module temperature variable can be considered in the first place. This is the surrounding ambient temperature in addition to the method for mounting the PV array as clarified above. Therefore, positioning the array 5in. from the surface of the roof will be the case. Based on this the temperature of the PV module will be estimated at 35°C above the ambient:

T_{mod} = 37°C +35°C = 72°C

$$V_{adj} = V_{mp} \times \left[100\% + \left((T_{mod} - 25℃) \times TC\ V_{mp}\right)\right] \quad (2)$$

Where,

- 25°C is the STC condition we must adjust from

- Vmp : rated maximum power voltage of the module
- Tmod : is PV the module temperature
- TC Vmp = Temperature correction factor in %/°C
- V_{adj} : is the temperature adjusted voltage.

Now, using the values supplied in our above example, we can easily solve for Vadj as follows:

The values provided in the above example can be used to calculate the V_{adj} as follows:

$$V_{adj} = 36.2 \times \left[100\% + \left((72℃ - 25℃) \times -0.45\%/°\mathrm{C}\right)\right]$$

$$= 36.2 \times \left[100\% + \left((47℃) \times -0.45\%/°\mathrm{C}\right)\right]$$

$$= 36.2 \times [78.85\%] = 28.5\ volt$$

Based on this, it is clear that 28.5 is the voltage value that will be produced by the PV module in mid-summer. Hence, it should be verified that a sufficient number of modules should be connected in series in order to keep the total amount of the adjust voltage of the modules above the minimum value that power electronics require, or below the maximum value at times of cold temperature. Assuming that there is an inverter which accepts a maximum value of 500V and a minimum value of 200V, it is possible to calculate how many modules it is acceptable to place in series as follows:

$$\boldsymbol{Maximum\ acceptable\ number\ of\ modules\ in\ a\ series} = {}^{500}/_{50.09} = 9.982\ modules$$

Therefore, 10 modules at maximum can be placed in series while staying in all temperatures expected below the maximum number.

On the low end:

$$\boldsymbol{Minimum\ acceptable\ number\ of\ modules\ in\ a\ series} = {}^{200}/_{28.54} = 7.007\ modules$$

Hence, seven modules in series are needed to stay above the minimum requirements. It is clear that these calculations are very important in the designing process of the PV module. Many manufacturers, such as those of grid-direct inverters, provide calculators on-line as a way to assist with these calculations.

2.2 PV System Voltage Drop:

Voltage drop is the name that commonly refers to the loss in electrical potential and it takes place at the time when a current flow goes between the source and load through a conductor. The amount of voltage drop, which is usually also referred to as wire loss, resistive losses or voltage rise, depends on conductor size and material, current and length and circuit voltage as well as many other factors including the temperature and the number of phases, the conductor geometry and raceway type. In the situation when a normal load is attached, a circuit conductor resistance and reactance get together to produce a small heating load which is fed in power by the circuit.

Two problems can be identified in PV system voltage drop. The first one is that this denotes wasted energy. The process of converting energy into heat in circuit conductors leads to energy production loss. The second problem is that in some conditions, PV inverters do not operate in a proper manner. For instance, there might be conditions where the dc bus voltage decreases to a level that is lower than the minimum MPPT voltage of the inverter or the ac bus voltage increases to higher level than the maximum set point of the grid voltage; in the former condition, would keep working but in a limited manner and in the latter condition, the inverter will not work at all. Photovoltaic system designers can reduce voltage drop through a strategic optimization of the schematic design and equipment layout. It is also possible to minimize voltage drop further by upsizing some conductors in the system.

2.3 Quantifying of Voltage Drop:

Quantifying of voltage drop is important to minimize and understand it. A circuit conductor is simply defined as a long low resistance electric heater which obeys Ohm's drop. The voltage is the result of the multiplication of the current by the resistance. The resistance depends on many factors such as the size, material, length and temperature of the conductor. A standard conductor has a typical value which is calculated according to the ohms per one thousand feet of conductor length. Based on this, the basic drop equation for dc voltage is calculated as:

$$V_{drop} = I \times r$$

$$V_{drop} = I \times (2 \times L \times R) = 2 \times L \times R \times I \tag{3}$$

In this equation, I represents the circuit current while L represents the one-way circuit length. As for R, it is the conductor resistance per one thousand feet. Importantly, it might be adjusted for single-phase, 3-phase or ac circuits, various power factors and temperatures.

The NEC is a very good start for the manual calculations of voltage drop. Although the NEC Handbook contains many voltage drop equations, examples and calculations, there is no certain amount of voltage drop specified. However, the notes on the circuits and feeders (Articles 210 and 215 respectively) suggest that if the voltage drop is less than three on every circuits and feeders and less than five percent in total, then an efficient operation is expected (210.19(A) fine print note (FPN) No. 4 and 215.2(A)(3) FPN No. 2.). Although such notes are a very useful reference for efficient operation, they are not binding or related to PV.

In Article 250.122(B), the code states that if the current, which carries conductors for voltage drop, is upsized, the equipment-grounding conductor (EGC) should also be upsized proportionally. However, it is still very important to upsize the equipment-grounding conductor of a PV system in order to address voltage drop (Article 690.45(A) *NEC* 2008). The sizing of equipment-grounding conductor in output circuits and PV source is usually adjusted according to table (250.122).

Voltage drop can also be calculated by the help of an electric calculator program. Such programs can be available online or downloaded directly to a computer. Importantly, these calculator programs very good and precise. Unfortunately, the answer cannot be verified because these calculator programs do not usually show how the calculations are done. Because some applications, such as PV, are not standard, it is not easy to adapt well to them. In this case, the best source for any project is an expert engineer who has good experience in voltage drop and PV issues.

Principles of Decreasing Voltage Drop:

- Transmitting at a higher voltage makes it possible to reach lower losses.
- If distances are shortened, there can be smaller voltage drops.
- Transmission of single phase with three phases is much more efficient.
- Large conductors will usually have lower voltage drop.
- Voltage drop of copper conductors is lower than that of aluminium conductors of the same size.
- Parallel conductors can be used for large ac circuits
- It is better to have power factors which are near the unity
- Decrease voltage drop which is decreased in the temperature of cooler conductors.
- The kind of conduit has no effect on the voltage drop of ac circuits which have power factor of (0.85 to 1) and conductors of a small size (less than 3/0). PVC is good, but when the size of wires is above 3/0 and the power factor is (0.85), aluminium is much better than steel. As for PV inverter-output circuits, when the size of wires is large and the power factor is close to 1.0, steel is more preferable than aluminium. Hence, the type of conductor used is very important for efficient performance.

2.4 Schematic Design and Equipment Layout:

If we put the above discussion into practice and discuss the possible challenges, we would imagine a situation where a 100 kW of power is transmitted from a PV array via a central inverter to a switchgear that is one thousand feet away, and the switchgear is from the last combiner box at the array. The question here is whether this imaginary situation is an example of a PV system with a possibility of voltage drop. The power in the above imaginary example can be transmitted in many ways. One possible way is to put the inverter next to the switchgear and cover the distance with a dc output from the combiner box. Another possible way is to put the inverter next to the combiner box and cover the distance with a 3-phase ac which has a normal voltage as instructed by the electric service and inverter output. It is also possible to allow use a 3-phase ac with high voltage to cover long distance transmission of power by adding step-up and step down transformers located at the interconnection and inverter. However, the standby and inefficiency losses of transformers should considered.

Based on the available type of AC site and PV string voltages, it is better to design the long distance run in direct current (DC) or alternative current (AC) to reduce voltage drop and costs. By following quick calculations, it shows the best way with minimum amount of voltage drop and cooper. When parallel conductors are used, the best way for long-distance runs is 700–800V_{DC}, which is the typical PV operating voltage where 1,000 V_{DC} systems are permitted. However, if the open-circuit voltage is restricted to 600V_{DC}, then 3-phase 480 V_{AC} is the best way for long runs. It is also recommended to use any direct current voltage with a value of 300–500V_{DC}. In fact, such PV voltages are preferred to single phase 277 V_{AC} or 3-phase 240V_{AC}. Based on the range and sizes of wires, these voltage phases are equivalent and good for long runs at 48 V_{DC} or 120 V_{AC}Vac.

Voltage drop on an AC motor circuit is worse than voltage drop on a similar DC circuit. When large size of conductors are used, the power factor is a crucial issue for designers. Based on the calculation in NEC (2008), the voltage drop in 85% power factor a single-phase DC circuit two-wire, using 300-kcmil conductors will be less than half the voltage drop of the same two-wire AC circuit using 300-kcmil conductors, for the same voltage and current. Therefore, the voltage drop in ac circuit is usually 5% more than the dc circuit in PV applications with power factor around 100%. Thus, the factors of voltage level and phases number in PV applications are more significant than the DC/AC differences.

2.5 Excess in Voltage Drop:

Upsizing the different circuit conductors and strategic design of the layout of the photo voltaic system are very important in any attempt to reduce voltage drop. It is very significant to keep voltage drop as low as possible in order to allow the inverters work as operate effectively. In order to achieve this, the inverter should not be lower than the MPPT of the inverter. In other words, after a decade or more of the module age with the highest possible temperature and full sunlight, the string voltage should be within the window of MPPT.

In addition to what mentioned above, there should not be considerable voltage drop in the ac output inverter circuit because such a scenario might lead into the highest limit of the inverter voltage. It is common in some parts of the day and the year that the grid voltage can be more than its nominal value. For instance, it possible for the inverter to be offline if there is an error of high grid voltage. That is, if the voltage of the inverter output circuit drops by 5%, the voltage of the grid at the interconnection may reach 252 V_{AC} line-to-line on a nominal 240 V_{AC} system. In such a case, the ac voltage at the inverter might reach 265V_{AC}, which is higher than the typical 264 V_{AC} high-voltage trip point. Therefore, any voltage drop should comply with the specifications of the project to save energy in wiring and satisfy the expectations of the owner. Typical bid packages have usually less than 2% voltage drop on every circuit of the AC and DC, and the total voltage drop from the modules to the interconnection is usually less than 3%.

III. Conclusion

This paper provides an introduction and analysis of a grid-connected photovoltaic power system that can be used as basic information for domestically used in houses. Moreover, the impact of temperature and irradiance on PV will be explained. In addition to that quantifyingsome significant data with some uselfequationsfor minimize and understand how to design and build a uself PV.

References:

[1] Plesser .R and HeffermanJ,"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.

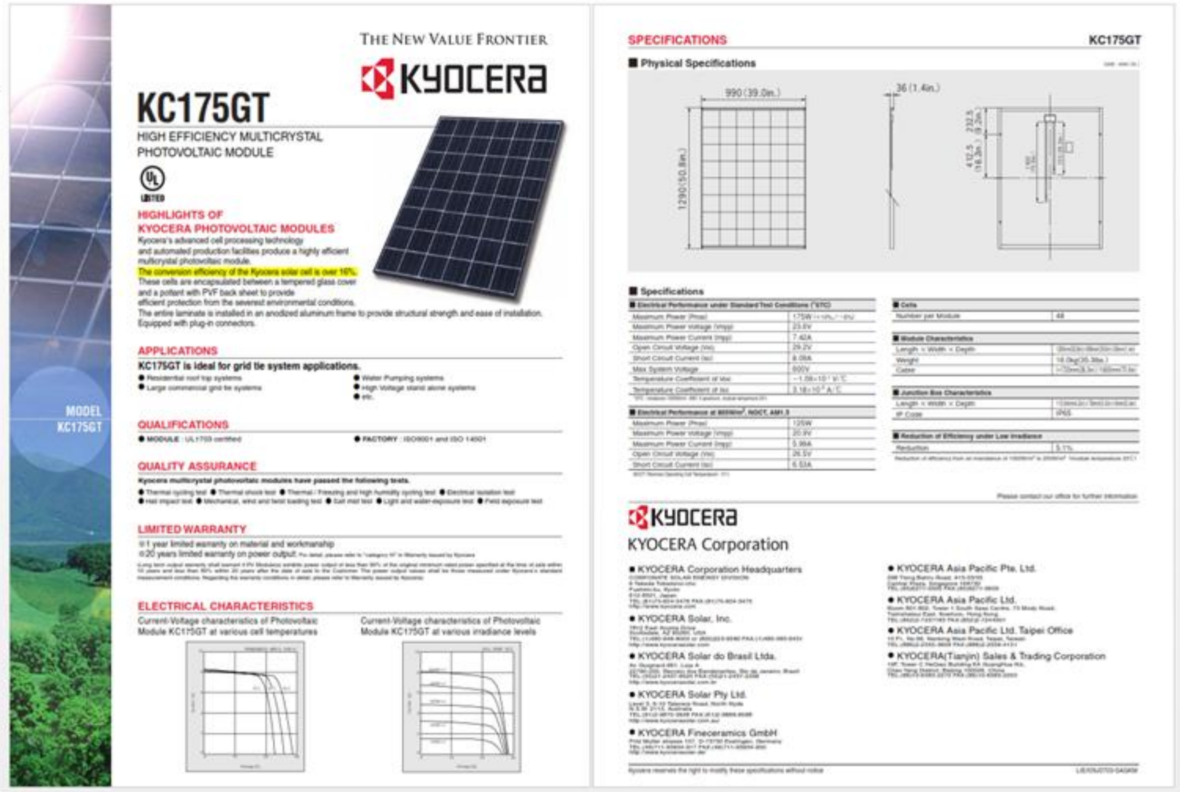
[8] Guillermo Velasco, FrancescGuinjoan, Robert Pique and Juan Jose Negroni. Sizing Factor Considerations for Grid-Connected PV Systems Based on a Central Inverter Configuration. IEEE Industrial Electronics, IECON 2006 - 32nd Annual Conference, pp 2718 - 2722 Dept. of Electron. Eng., Polytechnic Univ.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

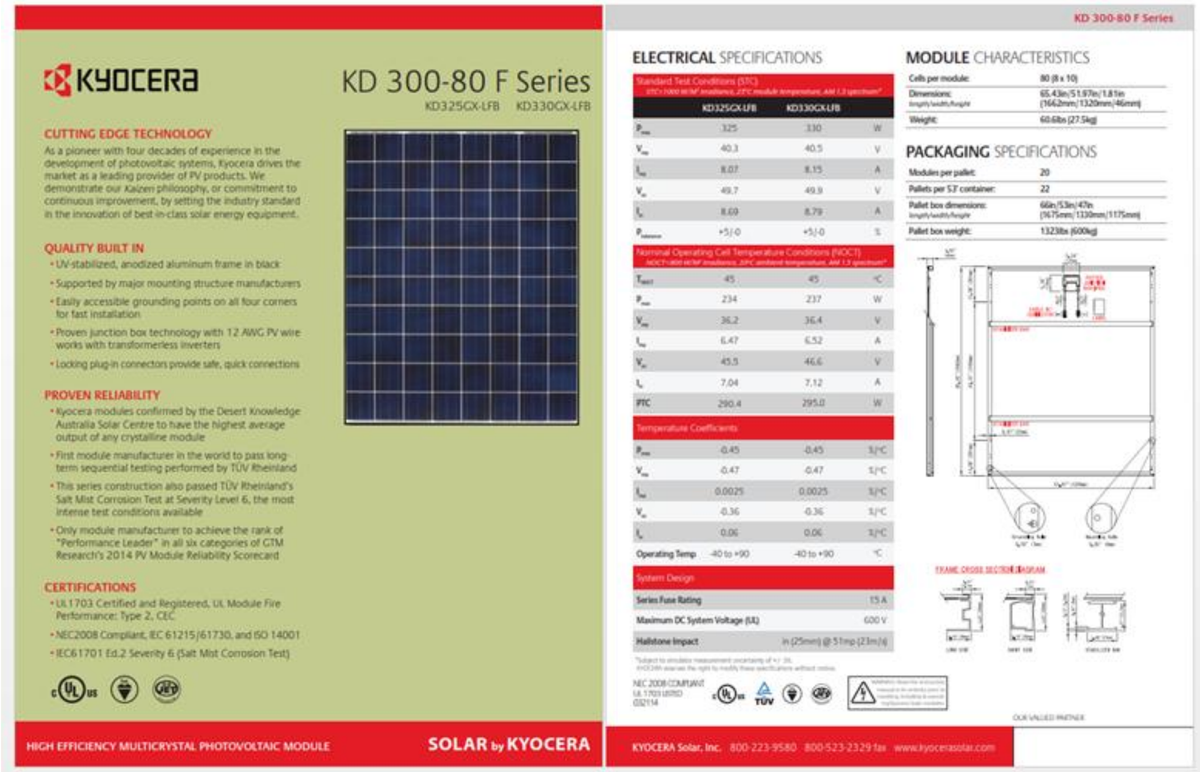
Appendix:

2006 ONWARDS

Parameters	**Definition**
AT	Atmospheric Temperature[^{o}C]
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 [^{o}C]
ATmn	Atmospheric Temperature minimum [^{o}C]
EVdtot	Evaporation difference total [mm]





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_{max}	325	330	W
V_{mp}	40.3	40.5	V
I_{mp}	8.07	8.15	A
V_{oc}	49.7	49.9	V
I_{sc}	8.69	8.79	A
$P_{tolerance}$	+5/-0	+5/-0	%
Nominal Operating Cell Temperature Conditions (NOCT)			
T_{NOCT}	45	45	°C
P_{max}	234	237	W
V_{mp}	36.2	36.4	V
I_{mp}	6.47	6.52	A
V_{oc}	45.5	46.6	V
I_{sc}	7.04	7.12	A
PTC	290.4	295.0	W
Temperature Coefficients			
P_{max}	-0.45	-0.45	%/°C
V_{mp}	-0.47	-0.47	%/°C
I_{mp}	0.0025	0.0025	%/°C
V_{oc}	-0.36	-0.36	%/°C
I_{sc}	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)

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

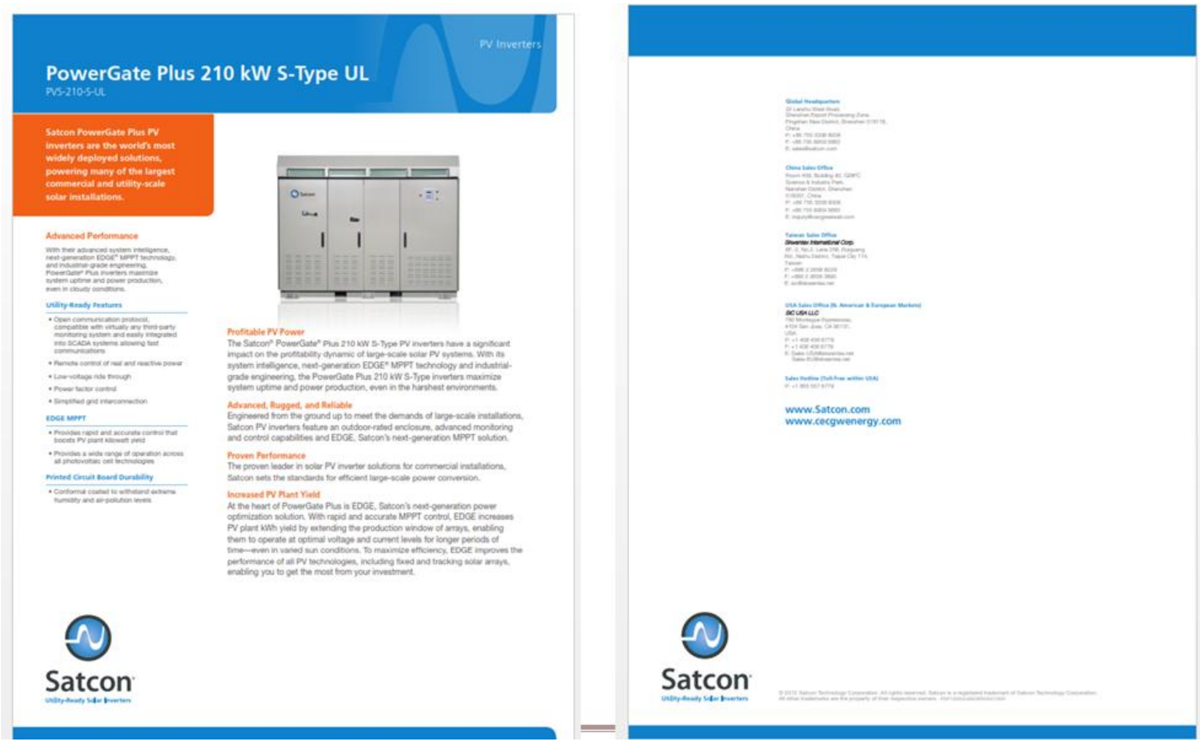
Modules per pallet:	20
Pallets per 53' container:	22
Pallet box dimensions: length/width/height	66in/53in/47in (1675mm/1330mm/1175mm)
Pallet box weight:	1323lbs (600kg)

FRAME CROSS SECTION DIAGRAM

NEC 2008 COMPLIANT
UL 1703 LISTED

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

With their advanced system intelligence, next-generation EDGE™ MPPT technology, and industrial-grade engineering, PowerGate® Plus inverters maximize system uptime and power production, even in cloudy conditions.

Utility-Ready Features

- Open communication protocol, compatible with virtually any third-party monitoring system and easily integrated into SCADA systems allowing fast communications
- Remote control of real and reactive power
- Low-voltage ride through
- Power factor control
- Simplified grid interconnection

EDGE MPPT

- Provides rapid and accurate control that boosts PV plant kilowatt yield
- Provides a wide range of operation across all photovoltaic cell technologies

Printed Circuit Board Durability

- Conformal coated to withstand extreme humidity and air-pollution levels

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
Utility-Ready Solar Inverters

www.Satcon.com
www.cecgwenergy.com

Satcon
Utility-Ready Solar Inverters