Skills Required To Design And Installations Of Solar Power For Domestic House

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Abstract : Design and installations of solar power for domestic house. A solar energy is sometimes refer to as an alternate energy system and while that’s true wind, geothermal and hydro system’s are also alternate energy system.

We will need one or more solar panel, a charge controller, a power inventor and also battery’s. In this installation first of all solar panel is connected to the charge controller then the charge controller to the battery’s after the battery connects to the power inventor. Surge arrestor is also used for reduce the damage of solar panel. Now a days everyone feel solar system is very costly and it is not economical and technology there can’t understand and more over there are not aware of this simple system. Our project to remove all misunderstanding of a common man or any graduate or diploma students can follow this project in order to built or more own solar system in his house.

Key points:
1. To reduce the greenhouse effect.
2. To reduce the power consumption.
3. To reduce the carbon content.

INTRODUCTION :

The sun radiates energy uniformly in all directions in the form of electromagnetic waves. The sun provides the energy needed to sustain life in our solar systems. It is a clean, inexhaustible, abundantly and universally available source of renewable energy. The major drawbacks of solar energy are that it is a dilute form of energy, which is available intermittently and uncertainly, and not steadily and continuously. However, it is more predictable than wind energy. Also, peak solar (incident solar radiation) often coincides with peak daytime demand; it can be well matched to suit commercial power needs. The outputs of the sun is 2.8*10²³ KW/year.

The energy reaching the earth is 105*10¹⁸ KWh/year. Solar energy can be utilized directly in two ways: (i) by collecting the radiant heat and using it in a thermal system, or (ii) by collecting and converting it directly to electrical energy using a photovoltaic system. The former is referred as ‘Solar Thermal’ and the latter as ‘Solar Photovoltaic’(SPV) system.

Solar energy is also used by various well-known natural effects and appears in nature in some other forms of energy. These are indirect forms of solar energy. Thus, solar energy is the mother of all forms of energy: conventional or non-conventional, renewable or non-renewable, the only exception being nuclear energy.

THE SUN AS A SOURCE OF ENERGY :

The sun, which is the largest member of the solar system, is a sphere of intensity hot gaseous matter having a diameter of 1.39*10⁸ m, and at an average distance of 1.495-10¹¹ m from the earth. As observed from the earth, the sun rotates on it’s axis about once in every four weeks, through it does not rotate as a solid body. The equator takes about 27days and the polar region takes about 30 days for each rotation. At the innermost region, the core, the temperature is estimated between 8*10⁶ to 40*10⁶ °k. The core has a density of about 100 times that of water and a pressure of 10⁴ atm. Such a high inner temperature is maintained by enormous energy released due to continuous fusion reaction. Thus, the sun is big natural fusion reactor with its constituent gases as the ‘containing vessel’ retained by gravitational forces. Several fusion reactions have been suggested to be the source of the energy radiated by the sun. The most important of them is a reaction in which four hydrogen atoms (protons) combine to form one helium atoms. The mass of the helium nucleus is less...
than that of four protons, the difference of mass having been converted to energy in a fusion reaction as follows:

\[ 4(\text{H}) \rightarrow \text{He}^4 + 26.7 \text{ MeV} \]

The surface of the sun is maintained at a temperature of approximately 5800°K.

THE EARTH:

The earth is shaped as an oblate spheroid—a sphere flattened at the poles and bulged in the plane normal to the poles. However for most practical purposes, the earth may be considered as a sphere with a diameter of about 1.275*10^7 m. The earth makes one rotation about its axis every 24 hours and completes a revolution about the sun in a period of approximately 365.25 days. Its axis is inclined at an angle of 23.5°. As a result, the length of days and nights keep changing. The earth reflects about 30% of the sunlight that falls on it. This is known as the earth’s albedo.

K = 1.38*10^-23 Joules/K (Boltzmann’s constant)

Using this formula, the energy-density distribution of solar radiation at the surface of the sun considering the surface temperature to be 5760°K can be calculated. Also, the same for the earth surface can be found out assuming the average earth temperature to be 288°K (15°C). The comparison of these radiations from the sun and the earth is shown. It is clear that the radiation emitted from the sun at about 5760°K lies in the range of short wavelengths, peaking around 0.48 µm and that from the earth at 288°K (15°C) lies in the range of long wavelengths, peaking around 10 µm.

SUN, EARTH RADIATION SPECTRUMS:

The energy radiated away from a black body temperature T and wavelength λ can be obtained from Planck’s black-body radiation formula:

\[ W_\lambda = \frac{2\pi h^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1} \]

Where \( h = 6.63*10^{-34} \text{ watt-sec}^2 \) (Planck’s constant)

Radiant powers per unit wavelength at the surface of the sun and earth

The term irradiate is defined as the measure of power density of sunlight received at a location on the earth density of sunlight and is measured in W/m². Irradiation is the measure of energy density of sunlight and is measured in kWh/m². It is generally denoted by the symbol H. Irradiance and irradiation apply to all components of solar radiation.

MONTHLY AVERAGE, DAILY GLOBAL RADIATION:
The correlation for estimating the monthly average daily total (global) radiation on a horizontal surface can be given as

\[ \frac{\bar{H}_g}{\bar{H}_o} = a + b \left( \frac{\bar{n}}{N} \right) \]

Where \( \bar{H}_g \) = monthly average, daily total radiation on a horizontal surface at a location.

\( \bar{H}_o \) = monthly average, daily extra-terrestrial radiation that would fall at the location on a horizontal surface (in the absence of an atmosphere)

\( \bar{n} \) = monthly average, daily hours of bright sunshine obtained from actual records at the location (i.e., bright sunshine hours)

\( N \) = monthly average of maximum possible daily hours of sunshine (i.e., the day length of the average day of the month)

\[ \frac{\bar{n}}{N} \] = p.u. possible bright sunshine

\( a, b \) = regression parameter are constants for a particular location and obtained by fitting data values of a and b have been obtained for many cities of the world. These values are given for some Indian cities.

\( \bar{H}_o \) is the mean or average of \( \bar{H}_o \) for each day of the month, which can be calculated as follows:

The extra-terrestrial radiation in kW/m² may be given as

\[ I_{\text{ext}} = I_{sc}\left[1.0 + 0.033 \cos\left(\frac{360n}{365}\right)\right] \]

On a horizontal surface, this would become, \( I_{\text{ext}} \cos \theta_z \)

The extraterrestrial radiation that would fall on a horizontal surface at the location may be written as

\[ I_{sc}\left[1.0 + 0.033 \cos\left(\frac{360n}{365}\right)\right] (\cos \phi \cos \delta \cos \omega + \sin \delta \sin \phi) \text{ (kW/m²)} \]

To get hourly radiated energy per square meter (i.e. in kJ/m²h), above term is to be multiplied by a factor of 3600:

\[ 3600* I_{sc}\left[1.0 + 0.033 \cos\left(\frac{360n}{365}\right)\right] (\cos \phi \cos \delta \cos \omega + \sin \delta \sin \phi) \text{ (kJ/m²h)} \]

One day radiation, \( H_o \) (in kJ/m²day) can be obtained by integrating the above expression over the day length where time is expressed in hours.

\[ H_o = 3600*I_{sc}\left[1.0 + 0.033 \cos\left(\frac{360n}{365}\right)\right] \int_{-\frac{\omega}{15}}^{\frac{180}{\pi}} \cos \phi \cos \delta \cos \omega + \sin \delta \sin \phi d\omega \]

As explained in above section. Since an hour of 15° is equivalent to 1 hour duration of sunshine, we have,

\[ t = \frac{\omega}{15} * \frac{180}{\pi} \]

Where t is hours and \( \omega \) is in radius.

Hence, \( dt = \frac{180}{15 \pi} d\omega \)

We have,

\[ H_o = 3600* \frac{12}{\pi} I_{sc}\left[1.0 + 0.033 \cos\left(\frac{360n}{365}\right)\right] \int_{-\frac{\omega}{15}}^{\frac{180}{\pi}} (\cos \phi \cos \delta \cos \omega + \sin \delta \sin \phi) d\omega \]

The calculation of \( H_o \) can be simplified from the fact that in each month, there is a particular day on which \( H_o \) is nearly equal to the monthly mean value \( H_o \). The dates on which the value of \( H_o \) are January 17, February 16, March 16, April 15, May 15, June 11, July 17, August 16, September 15, October 15, November 14 and December 10. As expected, the dates are close to the middle of the month. The values of sunshine hours for these dates are used as \( \bar{n} \) for that month.

Above equation can be used to determine the monthly average of daily global radiation on a horizontal surface at a location for known sunshine hours and where the values of a and b are known for a nearby location.

Other meteorological parameters have also been used for predicting the availability of solar radiation. These include cloud cover and precipitation.

However, in general, the sunshine ratio parameter \( \frac{\bar{n}}{N} \) has been found to be the most reliable predictor.
ESTIMATION OF SOLAR RADIATION OF GEOGRAPHICAL AREA POINT OF VIEW:

- **Latitude (angle of latitude), ($\phi$):**

  The latitude of a location on the earth’s surface is the angel made by a radial line joining the given location to the centre of the earth with its projection on the equator plane. The latitude is positive for northern hemisphere and negative for southern hemisphere.

- **Declination, ($\delta$):**

  It is defined as the angular displacement of the sun from the plane of the earth’s equator. It is positive when measured above the equatorial plane in the northern hemisphere. The declination $\delta$ can be approximately determined from the equation:

  $$\delta = 23.45 \times \sin\left(\frac{360}{365}(284 + n)\right)$$

  Where $n$ is day of the year counted from 1st January.

- **Hour Angle ($\omega$):**

  The hour angle at any moment is the angle through which the earth must turn to bring the meridian of the observer directly in line which the sun’s rays.

  In other words, at any moment, it is the angular displacement of the sun towards east or west of local meridian. The earth completes one rotation in 24 hours. Therefore, one hour corresponds to 15° of rotation. At solar noon, as the sun’s rays are in line with local meridian, the hour angle is zero. It is –ve in forenoon and +ve in the afternoon. Thus, at 06:00 h it is -90° and at 18:00 h it is +90°.

  It can be calculated as:

  $$\omega = (\text{solar time} - 12:00) \times 15 \text{ degrees}$$

- **Inclination Angle (altitude) ($\alpha$):**

  The angle between the sun’s ray and its projection on a horizontal surface is known as the inclination angle.

- **Zenith angle ($\theta_z$):**

  It is the angle between the sun’s ray and the perpendicular to the horizontal plane.

- **Solar Azimuth angle ($\gamma_s$):**
It is the angle on a horizontal plane, between the line due south and the projection of the sun’s ray on the horizontal plane. It is taken as +ve when measured from south towards west.

\[
\cos \theta_i = (\cos \phi \cos \beta + \sin \phi \sin \beta \cos \gamma) \cos \delta \cos \omega + \cos \delta \sin \omega \sin \beta \sin \gamma + \sin \delta (\sin \phi \cos \beta - \cos \phi \sin \beta \cos \gamma)
\]

Surface azimuth angle and slope (tilt angle)

Angle of latitude, tilt angle, angle of incidence

**ARRAY STRUCTURE:**

Wherever required, suitable number of PV panel structures shall be provided. Structures shall be of flat-plate design either I or L sections. Structural material shall be corrosion resistant and electrolytically compatible with the materials used in the module frame, its fasteners, nuts and bolts. Galvanizing should meet ASTM A-123 hot dipped galvanizing or equivalent which provides at least spraying thickness of 70 microns on steel as per IS5905, if steel frame is used. Aluminum frame structures with adequate strength and in accordance
with relevant BIS/ international standards can also be used.

Structures shall be supplied complete with all members to be compatible for allowing easy installation at the rooftop site. The structures shall be designed to allow easy replacement of any module & can be either designed to transfer point loads on the roof top or UDL as per site conditions. Each structure shall have a provision to adjust its angle of inclination to the horizontal as per the site conditions.

Each panel frame structure is so fabricated as to be fixed on the ground or roof. The structure should be capable of withstanding a wind load of 200 km/hr after grouting & installation. The front end of the solar array must be one meter above the ground. Grouting material for SPV structure shall be as per M15 (1:2:4) concrete specification.

The structures shall be designed for simple mechanical and electrical installation. There shall be no requirement of welding or complex machinery at the installation site. If prior civil work or support platform is absolutely essential to install the structures, the supplier shall clearly and unambiguously communicate such requirements along with their specifications in the bid. Detailed engineering drawings and instructions for such prior civil work shall be carried out prior to the supply of Goods.

The supplier shall specify installation details of the PV modules and the support structures with appropriate diagrams and drawings. Such details shall include, but not limited to, the following:

a. Determination of true south at the site;

b. Array tilt angle to the horizontal, with permitted tolerance;

c. Details with drawings for fixing the modules;

d. Details with drawings of fixing the junction/terminal boxes;

e. Interconnection details inside the junction/terminal boxes;

f. Structure installation details and drawings;

g. Electrical grounding (earthing);

h. Inter-panel/Inter-row distances with allowed tolerances; and

i. Safety precautions to be taken.

The array structure shall support SPV modules at a given orientation and absorb and transfer the mechanical loads to the rooftop columns properly. All nuts and bolts shall be of very good quality stainless steel.

ELECTRICAL SAFETY, EARTHING AND PROTECTION:

a. Internal Faults: In built protection for internal faults including excess temperature, commutation failure, overload and cooling fan failure (if fitted) is obligatory.

b. Over Voltage Protection: Over Voltage Protection against atmospheric lightning discharge to the PV array is required. Protection is to be provided against voltage fluctuations and internal faults in the power conditioner, operational errors and switching transients.

d. Earth fault supervision: An integrated earth fault device shall have to be provided to detect eventual earth fault on DC side and shall send message to the supervisory system.

e. Cabling practice: Cable connections must be made using PVC Cu cables, as per BIS standards. All cable connections must be made using suitable terminations for effective contact. The PVC Cu cables must be run in GL trays with covers for protection.

f. Fast acting semiconductor type current limiting fuses at the main busbar to protect from the grid short circuit contribution.

The PCU shall include an easily accessible emergency OFF button located at an appropriate position on the unit. The PCU shall include ground lugs for equipment and PV array grounding. All exposed surfaces of ferrous parts shall be thoroughly
cleaned, primed, and painted or otherwise suitably protected to survive a nominal 30 years design life of the unit.

The PCU enclosure shall be weatherproof and capable of surviving climatic changes and should keep the PCU intact under all conditions in the room where it will be housed. The INVERTER shall be located indoor and should be either wall / pad mounted. Moisture condensation and entry of rodents and insects shall be prevented in the PCU enclosure. Components and circuit boards mounted inside the enclosures shall be clearly identified with appropriate permanent designations, which shall also serve to identify the items on the supplied drawings.

All doors, covers, panels and cable exits shall be gasketed or otherwise designed to limit the entry of dust and moisture. All doors shall be equipped with locks. All openings shall be provided with grills or screens with openings no larger than 0.95 cm. (about 3x8 inch). In the design and fabrication of the PCU the site temperature (5° to 55°C), incident sunlight and the effect of ambient temperature on component life shall be considered carefully. Similar consideration shall be given to the heat sinking and thermal for blocking diodes and similar components.

FACTORY TESTING:

a. The PCU shall be tested to demonstrate operation of its control system and the ability to be automatically synchronized and connected in parallel with a utility service, prior to its shipment.

b. Operation of all controls, protective and instrumentation circuits shall be demonstrated by direct test if feasible or by simulation operation conditions for all parameters that cannot be directly tested.

c. Special attention shall be given to demonstration of utility service interface protection circuits and functions, including calibration and functional trip tests of faults and isolation protection equipment.

d. Operation of startup, disconnect and shutdown controls shall also be tested and demonstrate. Stable operation of the PCU and response to control signals shall also be tested and demonstrated.

e. Factory testing shall not only be limited to measurement of phase currents, efficiencies, harmonic content and power factor, but shall also include all other necessary tests/simulation required and requested by the Purchasers Engineers. Tests may be performed at 25, 50, 75 and 100 percent of the rated nominal power.

f. A factory Test Report (FTR) shall be supplied with the unit after all tests. The FTR shall include detailed description of all parameters tested qualified and warranted.'

g. Factory testing of the PCU/ PCU,s should be carried out and witnessed by the Purchaser’s Engineers at the manufacturers premises.

PLANT METERING/DATA LOGGING:

a) PV array energy production: Digital Meters to log the actual value of AC/DC Voltage, Current & Energy generated by the PV system shall have to be provided.

b) Solar Irradiance an integrating pyrometer (Class II or better) should be provided with the sensor mounted in the plane of the array. Readout should be integrated with data logging system.

c) Wind Speed: An integrated wind speed measurement unit is provided.

d) Temperature Sensor: Integrated temp, sensors for measuring the module surface temp., inverter inside enclosure temp, and ambient temp to be provided complete with readouts integrated with the data logging system.

MAXIMUM POWER POINT TRACKER (MPPT):

Maximum power point tracker shall be integrated in the PCU to maximize energy drawn from the array. The MPPT should be microprocessor based to minimize power losses. The details of working mechanism of MPPT shall be mentioned. The MPPT must have provision (.manual setting) for constant voltage operation.

ARRAY JUNCTION BOX, MAIN JUNCTION BOXES:
The junction boxes are to be provided in the PV yard for termination of connecting cables. The Junction Boxes shall be made of FRP/Powder Coated Aluminum with full dust, water & vermin proof arrangement. All wires/cables must be terminated through cable lugs. The J.Bs shall be such that input & output termination can be made through suitable cable glands. Made of FRP or cast aluminum/ copper.

Copper bus bars/terminal blocks housed in the junction box with suitable termination threads Conforming to IP65 standards and IEC 62208 Hinged door with EPDM rubber gasket to prevent water entry. Single compression cable glands. Provision of earthing Suitable capacity MOVs provided within the box to protect against lighting.

DC DISTRIBUTION BOARD:
DC Distribution panel to receive the DC output from the array field with analog measurement meter for voltage, current and power from different MJBs so as to check any failure in the array field.

DC DPBs shall have sheet from enclosure of dust & vermin proof. The bus bars are to made of copper of desired size. Suitable capacity MCBs be provided for controlling the DC power output to the PCU along with necessary surge arrestors.

AC DISTRIBUTION PANEL BOARD:
AC Distribution Panel Board (DPB) shall control the AC power from PCU, and should have necessary surge arrestors. Requirement/specifications of DCDB and ACDB may be changed as per site conditions. An ACDB to be provided at the cable terminating point emanating from 5 KVA PCU for interconnection control of dedicated electrical loads. All switches at the, circuit breakers, connectors should confirm to IEC 60947, part I, II and III.

CABLES & WIRES:
Cabling in the yard and control room: Cabling in the yard shall be carried out as per IE Rules. All other cabling above ground should be suitably mounted on cable trays with proper covers.

Wires: Only FRLS copper wires of appropriate size and of reputed make shall have to be used.

Cables Ends: All connections are to be made through suitable cable/lug/terminals; crimped properly & with use of Cable Glands.

Cable Marking: All cable/wires are to be marked in proper manner by good quality ferule or by other means so that the cable can be easily identified. Any change in cabling schedule/sizes if desired by the bidder/supplier be got approved after citing appropriate reasons, All cable schedules/layout drawings have to be got approved from the purchaser prior to installation. All cable tests and measurement methods should confirm to IEC 60189

BATTERY BANK:
The battery bank is to be designed to provide the backup power for feeding the dedicated loads in the event of failure of grid supply.

Storage Capacity: 96V, 900 Ah

Type: Tubular Gel batteries from reputed manufacturers. The battery cells shall have high ampere hour efficiency so as to quickly pick up the charge of the order 95%. High watt hour efficiency of at least 85%.

(i) The batteries shall be solar photo voltaic batteries of Tubular Gel type, low maintenance, lead Acid and made of hard rubber container.

(ii) The batteries shall use 2 / 12V cells and battery capacity is to be designed at C10 rate with end cell cut off voltage of 1.85 V / cell.

(iii) The self-discharge of batteries shall be less than 3 % per month at 20 deg. C and less than 6% per month at 30 deg. C. The charge efficiency shall be more than 90% up to 70% state of charge.

TOOLS & TACKLES AND SPARES:
A list of requisite spares in case of PCU comprising of a set of control logic cards, IGBT driver cards etc. Junction Boxes. Fuses, MCCBs etc. along with spare set of PV modules and batteries be indicated, which shall be supplied along with the equipment. A minimum set of spares shall be maintained in the plant itself for the entire period of warranty and
Operation & Maintenance which upon its use shall be replenished.

SOLAR PANEL:
Solar panels harness the sun's energy in the form of light and convert the energy into electricity. Although the average consumer might associate solar panels with residential rooftop assemblies, solar panels are available for a wide range of applications, including powering individual gadgets, electronic devices and vehicle batteries.

SOLAR PANEL:

CHARGE CONTROLLER:
A charge controller is needed to prevent overcharging of the batteries. Proper charging will prevent damage and increase the life and performance of the batteries.

CHARGE CONTROLLER:

POWER INVERTER:
The power inverter is the heart of the system. It makes 120 volts AC from the 12 volts DC stored in the batteries. It can also charge the batteries if connected to a generator or the AC line.

POWER INVERTER:

SURGE ARRESTORS:
Lightning strikes can cause great damage to your solar power system and can be mitigated using surge arrestors in the design loop. Surge arrestors act like “clamps” in most cases.

SURGE ARRESTORS:
BATTERIES:

Last are the storage batteries. They store the electrical power in the form of a chemical reactions. Without storage you would only have power when the sun was shining or the generator was running.

The relationship between the current and the voltage during the 3 phases of the charge cycle can be shown visually by the graph below.
ENERGY LOSSES AND EFFICIENCY:

The conversion efficiency of a solar cell is the ratio of electrical power output to incident solar power. In laboratory studies, the highest reported conversion efficiency of a single crystal silicon solar cell is about 24%. Conversion efficiencies of commercially produced single crystal solar cells are in the range 12-15%.

CONCLUSION:

As the production process of a solar cell is highly energy intensive, energy economy can only be achieved if energy payback period is low. A single crystal bulk silicon solar cell would have to continuously generate electrical energy for about 5 years before it starts providing energy in excess of what it has originally consumed during its manufacture.
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