Installation of Netmetering Grid Connected Solar Power Generation System for Residential Purpose

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***Abstract*— Now- a-days solar power generation plays an important role in the power generation for domestic, industrial or commercial purposes. Solar power is very clean and inexpensive. In the grid connected solar power generation system netmetering is a new technique which allows excess solar power generation during summer or bright sunny days which is fed to the utility grid after utilizing for residence. The energy can be imported from the utility grid during night and cloudy days. Netmeter consist of bi directional meter which reads both excess solar power which is sending in to the grid and import energy drawing from the grid. A residence is chosen as a case study. In the present work, solar photovoltaic power generation plant is installed on roof top of residence. Through this installation of solar photovoltaic system on roof top reducing in carbon gas emissions and electricity bill is observed.**

***Keywords*— solar photovoltaic system, import energy, excess solar power , netmetering, utility grid.**

I. INTRODUCTION

Solar energy has tremendous potential on the earth among all renewable energy sources like wind, tidal, geothermal, biomass. In India most places are receiving solar radiation an average of 4-7 kWh per square meter per day. Solar energy usages by people differ from place to place due to land availability, geography, time and clouds in sky. Solar power is conversion of solar energy in to electric energy. This conversion process can be done either indirectly by Concentrated Solar Power system (CSP) or directly by Photovoltaic system (PV). In concentrated solar power system sun energy indirectly converted through parabolic trough, fresnel lenses, power tower, solar dish collector. It requires more space, maintenance cost and installation costs are very high than the photo voltaic system. In photovoltaic system, sun energy is directly converted into solar power through solar modules which were made by semiconductor materials like mono and poly/multi crystalline silicon. Photovoltaic system requires less space, maintenance and operating costs are lower. This system is eco friendly. These are fastly growing technologies for roof top solar power generation.

II. LITERATURE SURVEY

India is emerging as one of the leader in solar power generation and has great potential to generate electricity from the solar energy. Guidelines for implementing of solar on grid application were given in the year 2008. Solar photo voltaic power generation system has classified as off grid and on grid /grid connected roof top systems. In the standalone off grid system, generating system is not connected to the utility grid therefore it requires battery storage. An off grid system has enough battery capacity to meet home's requirements. An Off grid system is very expensive than on grid system because cost of battery is high. So, it is mostly used in more remote areas where grid is not available at the plant. Since on grid system is connected to the utility grid, it does not require battery storage. In the grid connected system home loads run on solar power as long as sun energy available. In this system transmission loss is less because the utility grid is nearer to the power generation system. In grid connected photovoltaic system, DC power receives from solar panels and converted to AC power by power conditioning unit then AC power is fed back to grid through 3 phase/single phase line depending on capacity load.

III. GRID CONNECTED SOLAR POWER GENERATION SYSTEM COMPONENTS

A. Solar Photovoltaic Module

Solar cell/photovoltaic cell is an energy conversion device which converts sunlight in to electricity. Solar cells are connected in series or parallel to increase the electric power output. This connected assembly of solar cells called as solar photovoltaic module. This can be used as power generating component in the photovoltaic system. Single panel can produce only a limited amount of power. So, multiple panels are connected in series for generating required power from the system to meet home needs. Solar panels are made of semiconductor materials like mono silicon, poly/multi crystalline silicon, CdTe and Amorphous silicon. Solar module receives sun light energy from the surface which is covered by transparent glass. The sun light energy converted in to solar power through photo voltaic effect. Solar module's output is DC power.

B. Direct Current Distribution Box (DCDB)

Direct current distribution box is also called as array junction box or DCDB. It receives the DC power from the solar modules with surge protection device. Fuse is a protection device which is installed in DCDB to protect the solar panel strings. It contains two inlet and two outlet terminals for dc power supply. DC distribution box output is DC power which is sent to solar inverter.

C. Solar Grid Inverter

Solar inverter converts direct current which is received from solar modules to alternative current .It produces AC sinusoidal wave forms with low harmonic distortion. Inverter output varies with the solar radiation available at the plant. Inverter act as interface between photovoltaic system and grid. The inverter has protection features for over voltage and under voltage. It provided with the features of logging and display of parameters such as generation of solar power per day, DC voltage, AC voltage, DC current, AC current, DC power, AC power, AC frequency etc. The output AC power fed into the ac distribution box**.**

D. Alternative Current Distribution Box (ACDB)

It receives AC power from the solar inverter and directs it to ac loads in home. AC distribution box include surge protection device and MCCB to protect inverter cables from any type of damages. It has 3 power lines indicated by alphabet R, Y, B. These lines are connected to output terminals of solar inverter by suitable cable connecters. AC distribution box output lines are connected to the house AC main distribution box. Thereby AC power is transferred to all electrical equipments in home.

E. Netmeter

It is an energy meter installed in between solar grid inverter and residence main distribution box. Netmeter shows import and export energies in the LED display. The import and export energies are separately recorded in kWh and kVArh. Consumer shall pay the electricity bill depending on the net energy which is difference of export and import energies.

F. Mounting Structure

Mounting structure is important component in the solar power generation system. Solar panels are placed on this structure with the suitable tilt angle. Tilt angle of the structure is varying with latitude and longitude of the plant location. Intensity of sunlight will be utilized maximum when incident radiance is perpendicular to PV module. Hence orientation, tilt angle of panels and shading from surrounding obstructions is important design parameters. Structure is made of different materials like galvanized mild steel, aluminum based on location and grid load parameters. Structure is assembly of steel legs, angulars, columns and fasteners.

G. Protection Devices

Lighting arrestors, surge protectors, earthing and fuse are important protection devices in solar photovoltaic system. The main aim of the protection device is to reduce the over voltage to a tolerable value before it reaches the photovoltaic and other system components. In the solar photo voltaic system all electrical equipments and structural work are earthed by suitable earth electrodes.

IV. WORKING OF GRID CONNECTED SOLAR POWER GENERATION SYSTEM

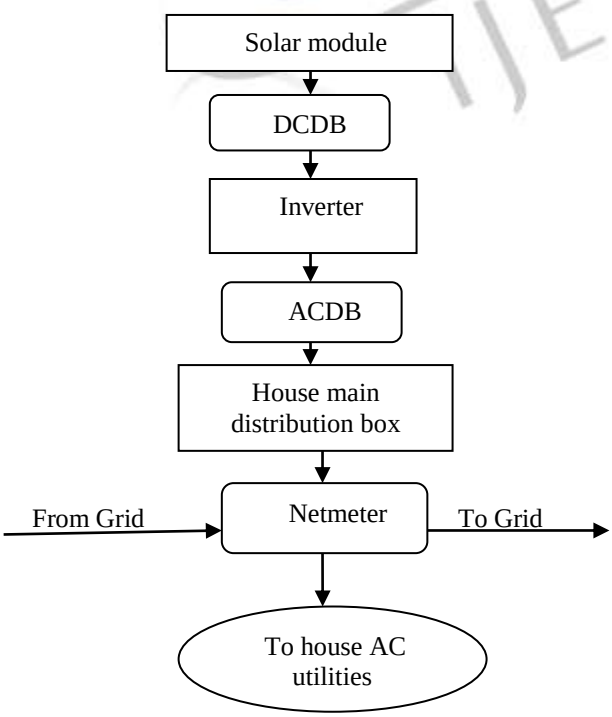

Fig. 1 Block Diagram of Solar Grid Connected Plant

In the grid connected solar power generation system solar modules exposed to sunlight then produces DC power by photovoltaic effect. Though solar photo voltaic array produces power when exposed to sunlight other components are required to properly conduct, control, convert, distribute and transform the energy produces by the array. The power generated by PV array is fed into the Direct Current Distribution Box (DCDB) through interconnection cables. Solar grid inverter receives DC power from the DCDB and converted to AC power. This AC power from the inverter sent in to the Alternative Current Distribution Box (ACDB). Then AC power fed in to the house AC distribution box which is connected to house electrical equipments and power grid. This system feds the AC power either to load or utility grid depends on solar power generation from the system. If the load demand is lesser than the solar power generated the balance power was exported to grid. Whenever solar energy is not sufficient due to cloud cover then the home loads are served by the drawing power from the grid. If grid supply is not available then the system shut off immediately. This system will shut off at the time of low intensity or no sun light and restarts automatically when sunlight is available. This system can work on either netmeter or gross meter.

V. INSTALLATION OF SOLAR PHOTOVOLTAIC SYSTEM ON ROOF TOP OF RESIDENCE

Installation process of grid connected system consist various stages such as

- Preliminary stage
- Implementation stage
- Final inspection stage

5.1 Preliminary stage

In this stage electrical load calculations, solar modules sizing, solar inverter sizing, mounting structure dimensions, payback period are calculating for the solar plant of residence

5.1.1 Residence location and geometric details

Address of site - 1/713, Dwaraka nagar.
Location - Kadapa
Longitude - $78^0$48" E
Latitude - 14^O28 N
Elevation - 138m
Average sunshine hours at this location: 5.6-6.0 hours

5.1.2 Electrical load calculations for residence

The total power consumed per day by all the appliances in the household is called electrical load of the house. In the household different electric appliances have different power outputs. So each electric appliance power is calculated by the multiplying of wattage with operating hours. The total electrical load of the residence was calculated as 34.840kWh per day.

Table 1 Load Calculations for Residence

Electric appliances	**Wattage (W)**	**Number in quantity**	**Number of hours consumption hours/day(hours)**	**Total consumption per day (kWh or UNITS)**
Tube light	40	6	10	2.4
Led bulb	10	6	9	0.540
Ceiling fan	50	5	18	4.5
Refrigerator	300	2	10	6.0
Lap top	100	3	9	2.7
TV	150	2	8	2.4
Electrical water pump	600	1	2	1.2
Air conditioner	3000	1	5	15.0
Iron box	50	1	2	0.1
			Total	34.840

Calculations:

Total electrical load per day - 34.840 kWh
Total electrical load per month - 1045.2 kWh
Total electrical load per year - 12542.4 kWh

5.1.3 Solar photovoltaic module sizing

Calculations:

For 1 kW system generate 4-5 units per day then system capacity required = $\frac{\text{Total energy consumption of house}}{\text{Energy generated for 1kW system}}$

= 34.74/4

= 8.685 kW

So it is preferred to install 10KW system on roof top and it generates 40-50 units per day.

Total number of panels required = $\frac{\text{Total capacity of system (W)}}{\text{Each module capacity (W)}}$

= 10000/315

= 31.7

Total 32 solar modules were required.

Number of solar panels in each string = $\frac{\text{Solar system voltage (Average)}}{\text{Each solar panel voltage (Maximum)}}$

= 600/37

=16.21

So, 16 panels required in each string.

Number of strings of solar modules = $\frac{\text{Total number of panels}}{\text{Solar panels in each string}}$

= 32/16 = 2

Table 2 Specifications of Solar PV Module

Manufacture by	RENEWSYS INDIA
Model	DESERV3M6-315
Rated power	315W
Open circuit voltage (Voc)	46.15V
Short circuit current(Isc)	8.91A
Maximum power (I_{mp})	8.55A
Maximum voltage(V_{mp})	36.92V
Number of modules	32
Number of modules in series	16
Number of arrays	2
Efficiency	16.26%
Size	1951mmX990mmX40mm

5.1.4 Solar grid inverter sizing

Calculations:

Total electrical load = $\frac{\text{Solar system capacity (kW)}}{\text{Power factor}}$

= 10/0.98

= 10.20 kVA

Inverter capacity should lies between 10-20 kVA.

Table 3 Solar Inverter Specifications

Manufacture by	DELTA
Model	RPIM10A
Maximum DC input current	15A/10A (for 2 strings)
Maximum DC input voltage	200-1000V
Maximum AC output current	25A
Maximum AC output voltage	230/380V
MPP	415-800V DC
Frequency	50/60 Hz
Size	612X625X278mm

Operating temperature	25^0-60^0

5.1.5 Mounting structure specifications

Roof top area of the house is measured as 1000 square feet. Roof top area of residence is suitable for install 10kw solar photo voltaic system. Solar panels placed with calculated tilt angle as15 ^{0} on this structure to receive the solar energy from the sun. Foundation base is mixture of concrete, sand and cement in the ratio of 1:2:4.Structure is fixed permanently in foundation base.

Table 4 Specifications of Mounting Structure Components

Structure material	Galvanized Mild Steel
Column angulars	4200mmX50mmX50mm
Row angular	4500mmX50mmX50mm
Front support legs	50mmX80mmX50mm
Middle support legs	800mmX80mmX50mm
Rare support legs	1420mmX80mmX50mm
Foundation base	300mmX300mmX280mm

5.1.6 Cable sizing

While making electrical connections in this system there is need to select an appropriate cable to minimize the voltage drop and power losses in cable.

Table 5 Specifications of AC, DC Cables

	Size	**Maximum voltage**	**Insulating type**
AC cable	$4mm^2$	1500v	LPE or LPO
DC cable	$6mm^2$	1000v	PVC or XLPE

5.1.7 Costing of the solar PV plant

Table 6 Cost and Quantity List of the plant

Equipment	**Quantity**	**Price (RS)**
Solar PV module	1	432000
Solar Grid Inverter	1	120000
ACDB,DCDB	1	32450
Netmeter	1	50200
Manual Fuse Switch Unit Box	1	10200
Cables ,PVC pipes		15150
Infrastructure		15000
Service Charges		10000
Travelling Expenses		15000
Maintenance Cost		10000
	Total cost	710000

Payback period of the system:

Plant capacity - 10kW

Solar power generation per day - 45 units (Average)

Annual generation - 16425units

Each unit cost above 500 units average Rs 10 per month

Annual savings = Rs 164250

Subsidy = 710000X 30%

= 213000RS

$$\text{Payback period} = \frac{\text{Total cost - Subsidy}}{\text{Annual savings}}$$

$$= \frac{710000-213000}{164250}$$

= 3 years

5.1.8 CO2 emissions avoided by the solar plant

Production of 1kWh electricity from conventional sources should generate 0.94kg of CO_2. From the calculations, installed system produced 40-50 kWh of electricity per day. So, 35-45 Kg of CO_2 per day reduced from the system

5.2 IMPLEMENTATION STAGE

5.2.1 Technical feasibility study

This study is based on application submitted by consumer with necessary information such as system size, interconnection voltage and choice of either netmetering or gross metering option. Then DISCOM personnel came and inspected whether the system satisfies the standards given by the CEA or not.

5.2.2 Commissioning process

Fig. 2 Solar Modules Array Structure

After completion of technical feasibility study, DISCOMS and consumer enters in to an agreement that specifies technical and commercial elements. DISCOMS provide approval based on check list. The Solar roof top photovoltaic system installed within 3 months from the date of agreement. In commissioning process all components like structure, solar module, solar inverter, ac and dc distribution box and manual switch fuse unit box are assembled as per the given layout of the solar photovoltaic plant.

5.2.3 Metering and synchronization

Fig. 3 Assembly of ACDB, DCDB &Inverter

After the commissioning process consumer should make request to DISCOMS for metering infrastructure through online mode. Then metering process would start and AP DISCOM should provide netmeter for the consumer. Netmeter must be satisfied standards given by the CEA & APERC. Synchronization is the process of solar photo voltaic system connecting with the grid by DISCOMS personnel after inspection and calibrating of plant capacity. Then DISCOM personnel seal the meter and assigned a service number for billing purpose.

5.3 Final inspection stage

DISCOM personnel has right to inspect solar photovoltaic plant at any time during the agreement. Solar modules, inverter, AC&DC distribution box and all protection equipments of systems are functioning as per IEC standards continue to meet the requirements of residence after installation till contract completion.

After completion of inspection stage energy billing process starts within one month. In billing process, if excess power injected in to utility grid in any month will be carried forward to the next month till every quarter. The bill settlement take place on average cost basis supply for netmetering as determined by APERC from time to time. Then excess consumption in any month payment should made by the consumer at applicable tariff.

VI. CONCLUSION

Grid connected solar power plant is successfully installed on roof top of residence. Present electricity bill of residence is reduced up to 92% when compared to previous electricity bill of residence.

Table 7 Electricity Bill Particulars Before

Month	Present reading (units)	Previous reading(units)	Net reading(units)	Amount (Rs)
Jul-aug 17	41292	40150	1142	9112

Table 8 Electricity Bill Particulars After

Jul-may-2018	Present reading (units)	Previous reading (units)		Net reading (units)	Amount(Rs)
Import	4930	3894	1036	-176	795
export	6503	5643	860		

Solar photovoltaic power generation system has 25 years of life span. Initial investment of the installed system is high but payback period of the system is 3 years only. Finally it can be concluded that installed system has reduced the electricity bill of residence. The CO_2 emissions in to the environment are also reduced.

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