Performance of Grid Connected Photovoltaic Systems with Net Metering For Commercial and Institutional Buildings

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ABSTRACT

The paper firstly introduces the solar energy principle of the present grid-connected PV generation system. The objective is to address both technical and financial aspects of a residential solar system. This paper describes the photovoltaic (PV) generation suitable for studying its interactions with the power system . Maximum power point tracking part of the control system of the PV generator dominates the dynamic behavior of the system . Net metering mechanism provides usages of a bi-directional meter which has facility to record both import and export energy values . With dramatic declines in the cost of solar PV technology over the last 5 years , the electricity industry is in the midst of discussions about whether to use this low polluting renewable energy source in grid-scale generation or in distributed generation mostly with rooftop solar PV.

Keyword : - *Net metering, solar system, efficiency, Grid connected PV Generation ,Commercial PV system.*

1. INTRODUCTION

As the concern over global warming increases, renewable energy source become a more significant source of energy. Among these renewable energy sources, photovoltaic (PV) generation is attracting a growing amount of political and commercial interest. With the increasingly urgent energy issues, the world attach great importance to begin the development of new energy and related technology. At present, large-scale photo voltaic power generation and scale of renewable energy has become important parts of development strategy, meanwhile it is the way to guide the development of photo voltaic industry . Solar photovoltaic can makes significant contribution towards some of the most energy problems now face by world. The main attraction of PV system is that they are abundant, pollution free and renewable. They produce electrical power without harming the environment by directly transforming a free in exhaustive source of energy, the solar energy into electricity. The photovoltaic installation mainly depends on the cost and efficiency of the generating system. The electricity generated from solar PV system can also be feed to distribution or transmission grid after conditioning to suit grid integration. Maximum power point tracking is used to obtain the maximum power form this system. In this applications the load can demand more power than the PV system can deliver.

SOLAR ENERGY PRINCIPLE:

The first question for solar users is "How much of the available solar energy can be converted to electricity in my location?" A photovoltaic (PV) module converts sunlight to direct current (DC) electricity. PV module ratings are listed for standard test conditions (STC). STCs are 1,000 W/m2solar irradiance and 25°C PV module temperature [7]. A 4 kW PV system corresponds to a PV array area of approximately 35 m2(377 ft2) [7]. PV output power is function of various factors, which that significantly impact the output generated power.

These factors are listed as follows:
• Geographical Location
• Shading
• Tilt angle and Orientation
• Material/Technology of the PV panel
• Efficiency of Non-PV modules

1.1 *Geographical Location*

Energy output of PV panels is highly dependent to their location. For example, solar panel in California will produce more energy than the identical one in Illinois. More irradiance results in more electrical energy production [8]. Therefore, if you are located closer to the equator, more electric energy can be produced than someone located further north or south with the same size system [18]. The optimal location for solar radiation can be determined using a "Solar Pathfinder" [8, 9].

1.2 *Shading*

PV modules energy output is highly sensitive to shading [7, 8]. The PV module output can be decreased to 20-30% of its rating if panel is shaded as much as a leafless tree branch [7, 8]. In a 20-30 years plan for installation of a solar system, young trees should be considered[7,8,10,].

1.3 *Tilt Angles and Orientation*

For a fixed PV array, the angle from horizontal of the inclination of the PV array is called the tilt angle [7] (0° = horizontal, 90° = vertical) as shown in Fig. 1. To maximize the annual energy production for fixed PV panels, the following rule of thumb is suggested to adjust the tilt angle [8]:
• latitude minus 15° in the summer
• latitude in the spring/fall
• latitude plus 15° in the winter

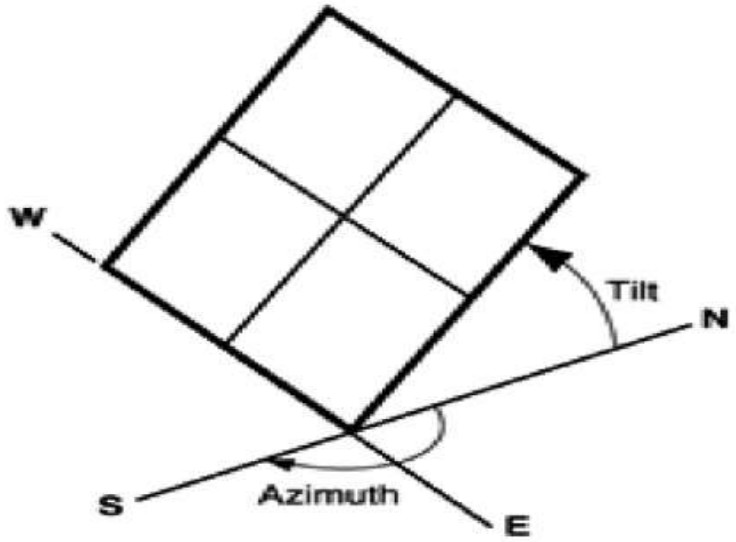

Fig. 1. PV array tilt angle and Azimuth [7]

Fig -1: PV array tilt angle and Azimuth

Solar users can generate more electricity by increasing the tilt angle in the winter and decreasing it in the summer. For a fixed PV array, the angle clockwise from true north that the PV array faces is called the azimuth angle [7].For a sun tracking PV array with one axis of rotation, the azimuth angle is the angle clockwise from true north of the axis of rotation [7]. For sun-tracking two-axis PV arrays, the azimuth and tilt angles are not applicable [7]. Normally, to maximum the energy production, the default value is an azimuth angle of 180° (facing south) is used for users located in the northern hemisphere and 0° (facing north) for users at the southern hemisphere[7].

2. GRID CONNECTED PV POWER GENERATION SYSTEM

Grid-connected PV generation system is mainly composed of the PV array, the inverter device with the function of maximum power tracking and the control system, whose structure shown in Fig. 1.

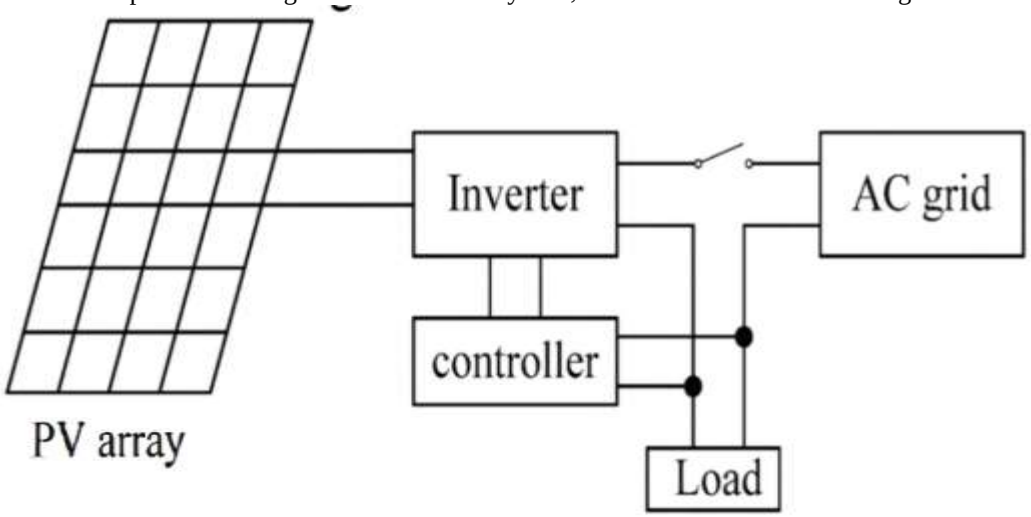

Fig. 1 Grid-connected PV power generation structure

Fig -2: Grid-connected PV power generation structure

The inverter device with the function of maximum power point tracking can inverse the electric power into sinusoidal current, and connect to the grid[6]. The control system mainly control the maximum power point tracking of photovoltaic, current waveform and power of the output of grid-connected inverter, which makes the output to the grid correspond with the export by PV array. The combination of and that maximizes the output of the inverter depends on the irradiance and is also affected by the temperature of the cells. A MPPT system is therefore always implemented to optimize the efficiency of the photovoltaic energy conversion. This tracking system adjusts the inverter voltage reference signal, and hence, the dc voltage at the output of the solar array. Various MPPT algorithms have been described in the literature [2]–[4]. The most common MPPT techniques are the open circuit voltage method, the incremental conductance method, the ripple-based method and the perturbation and observation (P&O) technique. A good MPPT technique should produce a high efficiency at a low cost because PV systems will have to be mass-produced. Rooftop solar PV is connected to the distribution system and ingestion of power is into a load center thereby avoiding transmission and distribution (T&D) losses incurred in the case of centralized, larger plants. This is a strong rationale for rooftop solar projects in India, where the national average of T&D losses hover at close to 30%.

3. COMMERCIAL AND INSTITUTIONAL(C&I) PV SYSTEM

These systems were described in Reference [1]. General information for each site is shown in Table 2; orientation data are based upon true north. Energy data for a typical year are shown in Table 3. Data for the GCH site were adjusted to compensate for metering and inverter problems. In contrast to the residential PV system inverters, the C & I inverters not have maximum power operating mode. The dc voltage operating point was set manually to a value representative of typical summer voltage and current. For this reason each C & I site is capable of producing more energy than that shown in table 3.Consideration is being given to installing a newly-designed power optimization circuit board in each inverter.

Table -1: GENERAL DATA FOR C&I PV SITES

Code	Peak power	Output (KWH/YR)	PEAK MONTH	PEAK MONTH OUTPUT
GL	2.4KW	2,600	AUG	280KWh
GCM	4.2KW	4,500	AUG	490KWh
GCC	7.3KW	8,000	AUG	850KWh
GBK	1.8KW	1,700	AUG	200KWh
CSF	3.9KW	4,100	AUG	410KWh
COB	4.8KW	5,000	MAR	530KWh
WPS	5.5KW	5,200	MAY	680 KWh

Table -2: ENERGY PRODUCTION DATA FOR C&I PV SITES

City& states	Type of building	Code	Tilt Angle(deg)	Orientation (deg)
Gardner MA	Library	GL	45	168
Gardner MA	City Hall	GCM	45	180
Gardner MA	College	GCC	45	180
Gardner MA	Restaurant	GBK	30	150
Gardner MA	store	GSF	45	180
Cranston RI	Police station	COB	45	200
Warwick RI	Police station	WPS	14	165

4. NET METERING AND THIRE POLICY

Net metering is an energy incentive policy for customers who generate electricity form their own small alternative energy devices such as wind turbines, solar panels or fuel cells [13]. As a motivation for customers who invest in renewable Energy generation, net metering is considered an energy incentive [13]. This policy allows customers to offset their consumption by flowing back their excess energy to the grid. It is an easy, low-cost method which can be achieved through a bidirectional meter. This meter spins backwards while the extra generated energy flows back to the grid and spins forward whenever electricity is purchased from the utility [12-14]. The utility bills the customer for the net amount the consumed energy at the end of the billing period [12,13,5]. Using this policy, utility customers generate their own energy and use it for their appliances by having a solar or a wind energy generation system. The excess generation can be stored in the grid, and be used whenever residents' electricity demand exceeds their local generation [12]. There is no need for installation of large storage devices such as batteries which are expensive, heavy and spacious. In addition, the full credit for the value of local generated electricity is achieved. Utility companies can benefit from net metering while customers produce extra energy during peak times [12]. As an example, a homeowner's PV system produces electrical Energy first to meet his home demands (e.g., appliances, lights) in the home. More generated electricity from the PV system than the home needs are flowed into the grid. At night or cloudy days, the needed energy can be purchased form the grid [14]. If there is no net metering, a second meter is needed to be installed to measure the electricity that flows back to the grid. The utility buys the extra power at a rate much lower than the retail price [12]. Net-metering program is required in most of the US states, but some of the laws only apply to investor-owned utilities not to municipal utilities or electrical cooperatives.

4.1 *Net Metering policy in India*

- Started in 2009.
- MNRE is undertaking this. Govt. is facilitating 30% of the total money as subsidy needed for equipping net metering system.
- For generating 1MW of electricity through net metering it costs about 7-8 crores in India. After installation plant gains about 1.6 crores per annum for 25 years.
- Kerala, Andhra Pradesh, Maharashtra are also well implementing this.

4.2 *Net Metering Policy in Maharashtra*

To promote the solar generation in Maharashtra the GOM has notified new Renewable Policy dated 20-07-2015 and methodology of Implementation on 09-09-2015. MERC has notified net metering for Roof-top Solar Photo Voltaic System regulations on 10th September 2015.

Summary of Net Metering Policy

Eligible Consumer: The LT/HT Consumer in MSDECL area having the capacity less than 1MW on a roof -top or any other mounting structure in his premises to meet all or part of his own electricity requirements , this also includes to a common load such as Housing Society. Such Solar System may be owned and operated by Consumer itself or by third party. The HT Consumers may install and Connect RSPV (Roof-top Solar Photo Voltaic) System at their LT bus bar system. The Cumulative capacity of all RSPV System shall not exceed the 40% of the rated capacity of the distribution transformer. Net Meter means an energy meter which is capable of recording both the import and export of electricity, or a pair of energy meters one for recording the import and the other for recording the export of electricity. Net Metering Arrangements means an arrangement under which RSPV System with net meter is installed at consumer premises delivers surplus electricity. The RSPV Capacity limits are

- For Single Phase 230/240 Volts Less than 8 kW/40 Amp.
- For Three Phase 400/415 Volts Less than 150 kW/187 KVA in Municipal area and less than 80 kW/100 KVA in other area.
- For 11 kV and above More than 150 kW/187 KVA and less than 1000 KVA in Municipal area and above 80 kW/100 KVA and less than 1000 KVA in other area.

The Net meter in the premises of the Eligible Consumer shall be procured and installed by MSEDCL. The Eligible Consumer may opt to procure, at his cost, the net meter for testing and installation by the MSEDCL. The MSEDCL shall be responsible for supply, installation testing and maintenance of the metering equipment. If Eligible consumer is within the TOD Tariff the Net meter install shall be capable of recording TOD consumption and generation. . For each billing period the Electricity exported and imported shall be shown separately. If the Exported electricity exceeds the imported during any billing period the excess quantum shall be carried to the next billing period as credited units of electricity. If the imported electricity exceeds the exported during any billing period the excess quantum bill shall be raise by MSEDCL after adjusting the credited units. The unadjusted net credited units of electricity at the end of each financial year shall be purchased by MSEDCL at its average cost of power purchase as approved by MERC. The Eligible consumer shall be able to pay the penalty charges, if the power factor is not maintained.

5. CONCLUSIONS

In this paper we conclude that the solar energy principles that help how the solar can be converted to electricity in my location .According to increasingly urgent energy issue there is a need to implement rooftop solar PV plant to fulfill the energy demand. Also the C&I PV system generate operate in a more hostile electrical environment .In consequence they have required more attention to maintain operating states and metering accuracy. It is also conclude that net metering which credit concept of solar energy system owner for the electricity and their policies.

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