Simulation Optimization and Parametric Study of a Grid Connected Solar Power Plant for Commercial Rooftop as well as on Utility Scale

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Abstract: As the nonrenewable energy sources is about to end, future of human energy needs is in renewable energy (solar, wind, hydro etc). Solar energy are using all over the globe at micro as well as utility scale. A wide variety of tools exist for the analysis and dimensioning of both Grid connected and stand-alone photovoltaic systems. System designers and installers use simpler tools for sizing the PV system. Mostly scientists and engineers typically use more involved simulation tools for optimization. In present study design, optimization of a grid connected solar power plant at commercial rooftop as well as on utility scale in INDIA is to be discussed. Design, simulation, Optimization is going on simulation facility like PVSYST.

Keywords: PVSYST, panel, tilt, field type.

I. INTRODUCTION

Renewable energy is the future of human. Due to the high consumption and the reducing availability of fossil fuel resource renewable energy (solar, wind, hydro etc) is subject to great interest over decades. Solar energy is an emerging renewable energy source using all over the globe at micro as well as utility scale. The power of sun intercepted by earth is greater than the present consumption rate on earth of all energy sources. So solar energy can provide solutions of all the present and future problems related to electricity. Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Photovoltaic’s convert light into an electric current using the photovoltaic. A rooftop photovoltaic power station, or rooftop PV system, is a photovoltaic system that has its electricity generating solar panels mounted on the rooftop of a residential or commercial building or structure. A photovoltaic (PV) system consists of a PV array, battery and elements for power conditioning. The PV system converts solar energy into dc power. If ac loads are used means, the system requires inverter to convert dc into ac.

There are two types in PV system such as grid connected and standalone. Grid connected photovoltaic systems feed electricity directly to the electrical network, operating parallel to the conventional energy source. Grid-connected systems generate clean electricity near the point of use, without the transmission and distribution losses or the need for the batteries. Its performance depends on the local climate, orientation and inclination of the PV array, and inverter performance. Whereas, a stand-alone system involves no interaction with a utility grid, the generated power is directly connected to the load. In case the PV array does not directly supply a load, a storage device is needed. Mostly this is a battery, the battery bank stores energy when the power supplied by the PV modules exceeds load demand and releases it back when the PV supply is insufficient. This standalone PV power generation will be used in the home for the electrification purpose. A wide variety of tools exist for the analysis and dimensioning of both Grid connected and stand-alone photovoltaic systems. System designers and installers use simpler tools for sizing the PV system. Mostly scientists and engineers typically use more involved simulation tools for optimization. Software tools related to photovoltaic systems can be classified into pre-feasibility analysis, sizing, and simulation.

PVsyst is a dedicated PC software package for PV systems. The software was developed by the University of Geneva. It integrates pre-feasibility, sizing and simulation support for PV systems. After defined the location and loads, the user selects the different components from a product database and the software automatically calculates the size of the system. In present study design, optimization and cost analysis of a solar power plant at residential, commercial rooftop as well as on utility scale in INDIA is to be discussed. Design, simulation, Optimization and cost analysis is going on simulation facility like PVSYST.

II. LITERATURE REVIEW AND PROBLEM FORMULATION

Various investigations have done on residential, commercial rooftop, Chen Zhang 2011 Designed technical shelter for storing electronic and technical equipments has high indoor heat dissipation rate, and cooling load exists almost all year around. Both experimental measurements and computer simulation are carried out to analyze the indoor. T.M. Ifakharet al 2012 shown grid connected
systems generate clean electricity near the point of use, without the transmission and distribution losses or the need for the batteries. Stand-alone system involves no interaction with a utility grid. Climate and energy performance of technical shelter in different conditions. C.P. Kandalama et al 2013 presented the simulation of a grid-connected solar photovoltaic system with the use of the computer software package Pvsyst and their performance was evaluated. Sangeetha S 2014 has investigated the sizing of the solar power plant in standalone mode of operation. Based on the load survey and the utilization factor, the capacity of the plant is determined for battery sizing and PV sizing. PVSYST and C programming are used for the sizing of the solar PV power plant. Sébastin Jacques Et al 2014 described a new, highly modular simulation tool named “PVLab” and developed by the GREMAN laboratory. It is designed to assist the designer in the sizing of PV (photovoltaic) installations. Jaydeep V. Ramoliya et al 2015 presented the simulation of a grid-connected solar photovoltaic system using the computer software package Pvsyst and their performance was evaluated. Jones K. Chacko 2015 investigated the major factors which affect the performance of the solar PV module three different arrangements of solar PV modules are taken on a standalone system and compared different panel arrangement that will minimize the floor area and maximize power generation through tracking the sun. By literature review it is clear that a comparative study of residential and utility scale PV system needed for efficient use of PV systems. Cost comparison will also give a better insight to efficient use a PV system.

III. RESEARCH METHODOLOGY

It is a computational study using Pvsyst software facility. PVSyst is simulation software able to simulate both stand alone and grid connected PV systems. Location of system is taken Delhi ncr region. Validation will conduct on the basis of previous investigation.

GRID CONNECTED SOLAR PV SYSTEM - A grid connected solar PV power plant is installing by compare the energy production, economic feasibility of some of the places in NORTH INDIA in DELHI using PVsyst Software. Proposed model of the grid connected PV system shown in figure. Tuticorin site is used for validation.

IV. VALIDATION

Geographical Location and Meteorology

Meteo data

Plane tilt and Azimuth

Horizon
Module and Inverter

V. VALIDATION RESULTS

Electricity injected into grid
PV plant on New Delhi Location:

- Electricity Production at New Delhi:

System Parameter

Geographical Site
- New Delhi, India
- Country: India

Situation
- Time defined as: 8:00 AM to 7:00 PM
- Latitude: 28.6 N
- Longitude: 77.2 E
- Altitude: 219 m

Metro data
- Solar plant: 20.5 kWh/day
- Solar panel efficiency: 15%
- Solar panel output: 1500 W
- Solar panel type: Monocrystalline

Simulation parameters
- Collector Plane Orientation: Tilt: 0°, Azimuth: 0°
- Models used:
  - Inverter: 24 kVA

Results:

Performance Ratio

| Month   | GridPr | GridPres | Egridprabhu | Egridpresent |
|---------|--------|----------|-------------|--------------|
| January | 143.2  | 137.8    | 137.8       | 137.8        |
| February| 137.3  | 148.6    | 137.8       | 137.8        |
| March   | 188.2  | 203.0    | 197.2       | 189.2        |
| April   | 200.5  | 213.4    | 207.7       | 198.9        |
| May     | 222.1  | 210.3    | 216.0       | 201.0        |
| June    | 159.5  | 160.3    | 157.135     | 157.032      |
| July    | 161.4  | 165.5    | 159.9       | 159.893      |
| August  | 158.9  | 161.0    | 156.0       | 156.087      |
| September| 170.6  | 171.5    | 170.3       | 168.917      |
| October | 164.5  | 168.2    | 166.7       | 165.896      |
| November| 125.8  | 134.7    | 129.067     | 128.039      |
| December| 115.1  | 137.4    | 122.76     | 121.801      |

| GridRaw | T Amb | GridInc | GridDC | EAray | E_Grid | E_Sol | E_Raw | E_RawPR |
|---------|-------|---------|--------|-------|--------|-------|-------|---------|
| 145.0   | 18.5  | 152.5   | 152.5  | 152.5 | 152.5  | 152.5 | 152.5 | 152.5   |

- Normalized productions (per installed kWp): Nominal power 1000 kWp
Comparison b/w Thiruvanantpuram and New Delhi

- Energy production per year at new Delhi location is 1707 Mwh.
- Energy production per year at Thiruvanantpuram location is 1707 Mwh.

Grid connected Plant at Delhi location; Location and Orientation

| System Parameters | Results |
|-------------------|---------|
| PV Array Characteristics | |
| Project: Grid-Connected Project at New Delhi | |
| Geographical Site | New Delhi | Country: India |
| Situation | Latitude: 28.6°N, Longitude: 77.2°E | |
| Time defined as | Legal Time, Zone UT+5.5 | |
| Albedo | 0.20 |
| Meteorological data | New Delhi, Meteonorm 7.1 station - Synthetic |
| Collector Plane Orientation | Tilt: 5°, Azimuth: 0° |
| Models used | Transp., Perez, Diffuse, Perez, Meteonorm |
| Horizon | Free horizon |
| Production | Normalized production (per installed kWp): Nominal power: 10.00 kWp |
| PR | Tilt, Performance Ratio (PR) |
| Balance and main results | |
| Main system parameters | |
| PV Field Orientation | Tilt: 5°, Azimuth: 0° |
| PV modules | Mono 230 Wp 48 cells |
| PV array | In series 10 modules, In parallel 4 strings |
| Total number of PV modules | 40 |
| Array global power | Nominal (STC): 10.00 kWp, At operating cond.: 0.87 Mwp (SOC) |
| Array operating characteristics (50°C) | U mp: 27.1 V, I mp: 3.3 A |
| Total area | Module area: 851.1 m², Cell area: 36.9 m² |
| Effects of Tilt and Location | |
| Inverter | 41 kWp inverter with 28PPT |
| Characteristics | Operating Voltage: 125-530 V, Unit Nom. Power: 4.3 kWac |
| Inverter pack | Nb. of inverters: 4, 28PPT 50%, Total Power: 8.4 kWac |
| System Production | Energy production: 16.32 kWh/year, Performance Ratio: 79.6% |

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DOI 10.17148/IARJSET.2017.4214
VI. RESULTS

Production for different Tilt
Tilt is taken 5, 10, 15, 20, 25 and 30 degree

Effect of plane type
Si-MONO Type Plane

Geographical Site: New Delhi
Country: India

- Latitude: 28.917°N
- Longitude: 77.21°E
- Time zone: UTC+5.5
- Elevation: 210 m
- Albedo: 0.20

- Meteo data: New Delhi - MeteoNorm 7.1 station - Synthetic

- Collector Plane-Orientation: Tilt: 30°
- Azimuth: 0°

- Simulation parameters
  - Models used:
    - Transportation: Perez
    - Diffuse: Perez
    - Meteor: Meteonorm
  - Horizon: Free Horizon

- PV Array Characteristics
  - PV module: Si-MONO
  - Mono 250 Wp 60 cells
  - Inverter Model: 4.2 kWac inverter with 2 MPPT

- Array Configuration:
  - In series: 10 modules
  - In parallel: 4 strings

- Total number of PV modules: 40
- Unit Nom. Power: 250 Wp

- Array global power: 10.00 kWac
- Operating cond. 3.87 kWp (50°C)

- Array operating characteristics (50°C)
  - Ump: 271 V
  - Iimp: 33 A
  - Total area: 65.1 m²
  - Cell area: 53.8 m²

Inverter
- Model: 4.2 kWac inverter with 2 MPPT
- Manufacturer: Generic
- Operating Voltage: 105–95 V
- Unit Nom. Power: 4.2 kWac
- Inverter pack:
  - No. of inverters: 4
  - MPPT 50 %
  - Total Power: 8.4 kWac

- PV Array losses factors
  - Thermal Loss factor: Uc (const)
    - 20.0 W/kWm
  - Uv (watts): 0.00 W/kWm

- Wiring Chomic Losses
  - Global array res. 141.6 kOhm
  - Loss Fraction: 1.5 % at STC

- Module Quality Loss
  - Loss Fraction: 0.6 %

- Module Mismatch Losses
  - Loss Fraction: 1.0 % at MPP

- Incidence effect, ASHRAE parameterization
  - IAM = 1 - be (loss - 1) / be Param
  - be = 0.05

Balances and main results

| Month | T-Ambient °C | Global H and E kWh/m² | Global E kWh/m² | Diffuse E kWh/m² | Direct E kWh/m² | GHI kWh/m² | GD kWh/m² | BE kWh/m² | Be kWh/m² | GHI % | GHI % | Diffuse % | Direct % | Diffuse % | Direct % |
|-------|--------------|-----------------------|-----------------|-----------------|-----------------|------------|-----------|-----------|-----------|--------|--------|-----------|----------|-----------|----------|
| Jan   | 110.0        | 13.33                 | 119.8           | 124.8           | 124.4           | 124.4      | 124.4     | 123.9     | 13.44     | 1.30   | 1.30   | 1.30      | 1.30     | 1.30      | 1.30     |
| Feb   | 127.3        | 17.24                 | 164.4           | 171.5           | 171.5           | 171.5      | 171.5     | 171.5     | 1.34     | 1.34   | 1.34   | 1.34      | 1.34     | 1.34      | 1.34     |
| Mar   | 192.2        | 23.29                 | 204.4           | 195.5           | 195.5           | 195.5      | 195.5     | 195.5     | 1.39     | 1.39   | 1.39   | 1.39      | 1.39     | 1.39      | 1.39     |
| Apr   | 280.5        | 29.32                 | 213.9           | 208.2           | 208.2           | 208.2      | 208.2     | 208.2     | 1.55     | 1.55   | 1.55   | 1.55      | 1.55     | 1.55      | 1.55     |
| May   | 333.3        | 32.61                 | 253.6           | 245.1           | 245.1           | 245.1      | 245.1     | 245.1     | 1.77     | 1.77   | 1.77   | 1.77      | 1.77     | 1.77      | 1.77     |
| Jun   | 195.5        | 32.14                 | 194.1           | 187.9           | 187.9           | 187.9      | 187.9     | 187.9     | 1.45     | 1.45   | 1.45   | 1.45      | 1.45     | 1.45      | 1.45     |
| July  | 196.4        | 71.42                 | 165.2           | 153.4           | 153.4           | 153.4      | 153.4     | 153.4     | 1.50     | 1.50   | 1.50   | 1.50      | 1.50     | 1.50      | 1.50     |
| Aug   | 159.9        | 39.36                 | 161.8           | 150.3           | 150.3           | 150.3      | 150.3     | 150.3     | 1.71     | 1.71   | 1.71   | 1.71      | 1.71     | 1.71      | 1.71     |
| Sept  | 170.5        | 29.05                 | 186.3           | 173.0           | 173.0           | 173.0      | 173.0     | 173.0     | 1.42     | 1.42   | 1.42   | 1.42      | 1.42     | 1.42      | 1.42     |
| Oct   | 196.4        | 25.49                 | 120.9           | 170.3           | 170.3           | 170.3      | 170.3     | 170.3     | 1.47     | 1.47   | 1.47   | 1.47      | 1.47     | 1.47      | 1.47     |
| Nov   | 126.5        | 19.15                 | 111.9           | 145.6           | 145.6           | 145.6      | 145.6     | 145.6     | 1.29     | 1.29   | 1.29   | 1.29      | 1.29     | 1.29      | 1.29     |
| Dec   | 115.1        | 16.65                 | 137.7           | 134.4           | 134.4           | 134.4      | 134.4     | 134.4     | 1.25     | 1.25   | 1.25   | 1.25      | 1.25     | 1.25      | 1.25     |
Results

Si-Poly type

A-Si:H single type
Results of plane type

Effect of Type of field
Fixed plane type field

Geographical Site: New Delhi
Country: India
Situation: Time defined as
Metro data: New Delhi

Results of plane type

Effect of Type of field
Fixed plane type field

Geographical Site: New Delhi
Country: India
Situation: Time defined as
Metro data: New Delhi
Sessional tilt type field


dailies and main results

| Month | Global | T. Amb. | Global | T. Amb. | Direct | Diffuse | Total |
|-------|--------|--------|--------|--------|--------|---------|-------|
| Jan.  | 191.2  | 13.20  | 191.2  | 13.20  | 151.2  | 40.0    | 191.2  |
| Feb.  | 187.0  | 13.00  | 187.0  | 13.00  | 143.0  | 44.0    | 187.0  |
| March | 199.2  | 23.20  | 201.2  | 23.20  | 179.2  | 22.0    | 199.2  |
| April | 218.8  | 28.20  | 218.8  | 28.20  | 200.8  | 18.0    | 218.8  |
| May   | 222.5  | 32.00  | 222.5  | 32.00  | 187.5  | 35.0    | 222.5  |
| June  | 168.2  | 20.14  | 168.2  | 20.14  | 138.2  | 30.0    | 168.2  |
| July  | 166.0  | 21.62  | 166.0  | 21.62  | 136.0  | 30.0    | 166.0  |
| August | 118.9  | 26.38  | 118.9  | 26.38  | 98.9   | 20.0    | 118.9  |
| September | 171.9  | 26.38  | 171.9  | 26.38  | 131.9  | 30.0    | 171.9  |
| October | 154.2  | 28.42  | 154.2  | 28.42  | 124.2  | 20.0    | 154.2  |
| November | 126.3  | 18.32  | 126.3  | 18.32  | 96.3   | 20.0    | 126.3  |
| December | 111.4  | 18.32  | 111.4  | 18.32  | 81.4   | 20.0    | 111.4  |
| Year   | 1757.5 | 00.05  | 1757.5 | 00.05  | 1387.5 | 370.0   | 1757.5 |

Normalized production per installed kWp: Nominal power 10.00 kWp

| Month | Gen. Loss | Array | Indirect | Prod. Out. | Total |
|-------|-----------|------|----------|------------|-------|
| Jan.  | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| Feb.  | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| March | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| April | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| May   | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| June  | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| July  | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| August | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| September | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| October | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| November | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| December | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |
| Year   | 0.11 KWh/KWp | 0.10 KWh/KWp | 0.01 KWh/KWp | 0.22 KWh/KWp |       |

VII. CONCLUSION

Computational method is a effective one for analysis and design of a solar panel power plant. In present study analysis is done for grid connected solar system, a parametric analysis is presented in this study. Energy production from a grid connected solar panel system is increased with increasing tilt angle. Sessional tilt will give large production of energy in comparison to fixed type and shading type.

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