Performance Analysis of 10MW Solar PV Grid Connected power Plant Established by KPCL at Shivanasamudram

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Abstract –*Energy in one form or the other is a basic input for sustenance of life on this planet not only for human beings living on it, but also the flora and fauna. The most abundant and never failing source of energy that is bestowed on the earth is, of course, solar energy without which there will be no wind, no rain, no vegetation, no rivers, no tides, and no agriculture and so on.*

The favorable climate conditions of the place called Shivanasamudram of Mandya district in the state of Karnataka and the recent legislation for utilization of renewable energy sources provide a substantial incentive for Installation of photovoltaic power plants in this paper, the grid connected solar photovoltaic power plant established by Karnataka Power Corporation Limited is presented, and its performance is evaluated. The photovoltaic power plant has A solar radiation of 4.37 kWh/sq.mt/day spread over 48 Acres of land. Operating module temperature varies from 15 to40 degree centigrade, with a tilt angle of module 13 degree and guaranteed energy generated is 16.3224MU/Annum with 18.55% CUF. The plant has been in operation since 2015. The power plant is suitably monitored during 2016 , and the performance ratio and the various power losses (temperature, soiling, internal, network, power electronics, grid availability and interconnection) are calculated and the performance ratio (PR) ranged from 87 to 90%, giving an annual PR of 87.81%.

Key Words: **Photovoltaic**, **Grid**, **Tilt angle**, **Capacity Utilization Factor (CUF), Performance Ratio(PR), kWh, Million Units (MU).**

1. INTRODUCTION

About half the incoming solar energy is absorbed by water and land; the rest is reradiated back into space. Earth continuously receives 340 W/m² of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by the atmosphere, oceans and land masses. After passing through the atmosphere, the insolation spectrum is split between the visible and infrared ranges with a small part in the ultraviolet. The absorption of solar energy by atmospheric convection (sensible heat transport) and evaporation and condensation of water vapor (latent heat transport) powers the water cycle and drives the winds. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. The conversion of solar energy into chemical energy via photosynthesis produces food, wood and the biomass from which fossil fuels are derived. Solar radiation, along with secondary solar resources such as wind and wave power, hydroelectricity and biomass, account for over 99.9% of the available flow of renewable energy on Earth.

1.1 Latitude (φ): Latitude is defined as the number of degrees north or south of the equator. The latitude affects where the sun is positioned in the sky throughout each day (relative to the position). Lines of latitude appear straight and horizontal in the projection above, but are actually circular with different radii. All locations with given latitude are collectively referred to as a circle of latitude.

1.2Tilt angle (⁰c): To get the most from solar panels, it needs to point them in the direction that captures the most sun. But there are a number of variables in figuring out the best direction. It is designed to help to find the best placement for the solar panels in the situation. This advice applies to any type of panel that gets energy from the sun; photovoltaic, solar hot water, etc. We assume that the panel is fixed, or has a tilt that can be adjusted seasonally.

2. SOLAR PHOTOVOLATIC

Solar photovoltaic is the device which converts the incident solar energy directly into DC electricity using solar cell and then converting into AC for power the load or feeding to grid.

2.1 Theory of Solar Cells: A solar cell is based upon the "photovoltaic effect" discovered in 1839 by Edmund Becquerel, a French physicist. In his experiments he found that certain materials would produce small amounts of electric current when exposed to sunlight. Sunlight is made up of packets of energy called photons. When the photons strike the semi-conductor layer (usually silicon) of a solar cell a portion of the photons are absorbed by the material rather than bouncing off of it or going through the material. When a photon is absorbed the energy of that photon is transferred to an electron in an atom of the cell causing the electron to escape from its normal position. This creates, in essence, a hole in the atom. This hole will attract another electron from a nearby atom now creating yet another whole, which in turn is again filled by an electron from another atom. This moment of electron and holes process is repeated a few zillion times and voila, an electric current is formed.

2.2 PHOTOVOLTAIC EFFECT: The photovoltaic effect involves the creation of a voltage (or a corresponding electric current) in a material upon exposure to electro-magnetic radiation. Though the process is directly related to the photoelectric effect, the two processes are different and should be distinguished. Photovoltaic Effect is the effect that causes a voltage to be developed across the junction of two different materials when they are exposed to light. In the photoelectric effect electrons are ejected from a materials surface upon exposure to radiation of sufficient energy. The photovoltaic effect is different in that the generated electrons are transferred from one material to another resulting in the buildup of a voltage between two electrodes.

3. TYPES OF PV INSTALLATION

3.1. STAND ALONE:

These systems can generate, store and deliver power without depending on the electricity supply Small stand-alone SPV systems can power systems like:

Home lighting and Street lights Garden lights and Illuminated hoardings,Water pumps Depending on the nature of the load, stand-alone SPV systems are designed with or without storage battery:

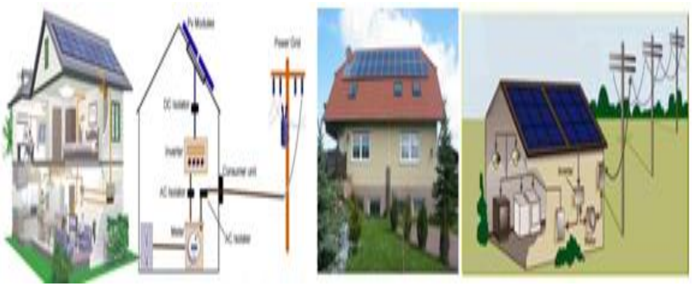

Figure 11: photovoltaic grid connected system with net metering

Those who would like to achieve long-term energy independence solar photovoltaic (PV) systems using solar panels are one of the very best options. Solar energy systems for the home are relatively simple, last for decades and over the long term can save homeowners significant money, particularly in those states or countries that provide incentives for solar energy. Moreover, solar PV systems create no pollution and give off no hydrocarbons which make them one of the best energy options from an environmental standpoint. A key thing to remember with PV systems is that what they are harvesting is light energy, not heat or solar thermal energy.

That means they work as well in colder climates as they do in warmer climates. All that matters is how much light a location gets and how many hours of sunlight per day your area gets at different times of the year with is more than sufficient light on average for PV systems to be very effective Photovoltaic systems (PV) are any energy generation systems that make use of photovoltaic cells. A photovoltaic cell is a cell which generates electricity directly from light energy. Photovoltaic cells come in many sizes, but most are 10 cm by 10 cm and generate a little more than half a volt of electricity. PV cells are bundled together in interconnected solar panels to produce higher voltages and increased power. A 12-volt solar panel typically used in home solar energy applications has 30 to 50 PV cells. and can generate anywhere between 80 to 200 volts of electricity. In a residential application multiple solar panels are strung together into one or more modules. The number of panels you need is a function of your energy use and the amount of space you have available on your southern (South Facing) facing roof.

3.2 GRID CONNECTED SOLAR PV POWER PLANT:

Pre-engineered photovoltaic systems can be purchased that come with all the components it will need, right down to the nuts and bolts. Any good dealer can size and specify systems for the given a description of the site and needs. Nevertheless, familiarity with system components, the different types that are available, and criteria for making a selection is important. Basic components of grid-connected PV systems with and without batteries are:

1. Solar photovoltaic modules and Array mounting racks
2. Grounding equipment and Combiner box
3. Surge protection (often part of the combiner box)
4. Inverter and Meters – system meter and kilowatt-hour meter
5. Disconnects:
6. Array DC disconnect and , Inverter DC disconnect
7. Inverter AC disconnect and Exterior AC disconnect

4. METHODOLOGY

4.1 PVSyst

PVSyst contains parameters that can be customized based on the solar module to be modeled. In this paper, we'll provide details on how to alter specific parameters to deliver an accurate representation of output from Sun Edison Silvantis modules. GIGO: PVSyst uses an input file with the extension

".PAN" that provides specific module parameters as simulation inputs. Simulation input files can be created from measurements of production modules under various conditions of temperature and irradiance. While some manufacturers create their own PAN files, Sun Edison's PAN files are created by independent, accredited test laboratories. These labs measure randomly selected production modules, then create PAN files using regression analysis techniques.

4.2 PV watts Calculator

NREL's PVWatts calculates the energy production of grid-connected photovoltaic (PV) energy systems. This service estimates the performance of hypothetical residential and small commercial PV installations.

PVWatts Version 5 is a major update to the algorithms that were used in previous versions of the PVWatts web services. Compared with PVWatts Version 4, our new update will predict roughly 7-9% greater energy output for a fixed tilt system given similar assumptions. The new results much more closely match measured system performance data, and address concerns that PVWatts Version 4 tended to under-predict PV system performance given the default input assumptions.

PVWatts uses the NREL NSRDB 1961-1990 TMY2 dataset as the default option. However, you can select to use NREL NSRDB 1991-2005 TMY3 data, international data, or a 10km gridded dataset covering all of India

PVWatts calculator calculates the energy production and cost savings of connected to the grid photovoltaic (PV) systems throughout the world (USA, UK, Europe, France, Italy, Spain...) totally free; it allows anybody to easily estimate the performance of worldwide PV projects.

PVWatts calculator provides also estimated monthly and annual irradiation and energy production in kilowatts and energy value. Users can select a location and choose to use default values or their own system parameters for size, electric cost, array type, tilt angle, and azimuth angle. In addition, the PVWatts calculator can provide hourly performance data for the selected location.

4.3 RETScreen Expert

Main activities and outputs · Build a large and evolving global database of project input parameters (including data on benchmarks, facilities, archetypes, costs, products, and finances) · Create an expert system decision-engine within the software that will mine this database relative to the user's project location · Gather publically available data for multiple regions, based on the existing climate data in RETScreen · Link to open data sources and energy resource maps such as NASA's satellite weather data, streaming dynamic near real time data into the software · Use the above to underpin the creation of a Virtual Energy Analyzer, a Smart Project Identifier, Financial Risk Assessor and project lifecycle Performance Tracker · Create training material · Conduct beta testing/pilot project in a REEEP priority country Expected impacts · Dramatic reduction in financial and time costs to identify and assess potential clean energy investments · Direct user savings of more than $ 20 billion achieved by the end of 2022 · RETScreen Expert used for at least $ 100 billion in project investments · Emission reductions of at least 50 MT CO2/year in greenhouse gas emissions achieved · Substantial contribution to global economic development, greenhouse gas and pollution reduction, and energy security

4.4 SCADA SYSTEM:

The task of supervision of machinery and industrial processes on a routine basis can be an excruciatingly tiresome job. Always being by the side a machine or being on a 24x7 patrol duty around the assembly line equipment checking the temperature levels, water levels, oil level and performing other checks would be considered a wastage of the expertise of the technician on trivial tasks. But, to get rid of this burdensome task, the engineers devised equipments and sensors that would prevent or at least reduce the frequency of these routine checks. As a result of that, control systems and it's various off springs like SCADA systems were formed. Supervisory Control And Data Acquisition (SCADA) offers the ease of monitoring of sensors placed at distances, from one central location.

Table -1: TECHNICAL DETAILS OF PV MODULE AT SHIVANASAMUDRA

Sl. no	DESCRIPTION	DETAILS
1	Type of SPV module	Poly Crystalline
2	PV module power output	Min 285 Watts 36V
3	Total no. of module used	35840
4	No. of Module per MW	3584
5	Array rating	259.5 KW
6	Details of series/parallel combination	20 Nos. in series 1792 parallel string
7	Tilt angle	13^0
8	Temperature	Min 15 ^{0}C Max 40 ^{0}C

5. PERFORMANCE EVALUATION

Performance evaluation of Grid Connected Solar PV Plant is based on the parameters namely;

1. Air temperature (°C),
2. Relative humidity (%),
3. Daily solar radiation – horizontal (kWh/m^2/d) ,
4. Atmospheric pressure (k Pa),

5. Wind speed (m/s), Earth temperature (°C),
6. Heating degree-days (°C-d), cooling degree-days (°C-d).

Table-2: Location Specifications

PARAMETERS	Unit	Climate data location
Latitude	°N	12.3
Longitude	°E	77.16
Elevation	m	723
Heating design temperature	°C	16.78
Cooling design temperature	°C	14.71
Earth temperature amplitude	°C	14.71
Frost days at site	day	0

Table -3: Monthly output energy during year 2016 and also PVSyst and NREL software monthly average energy output

Months	PVSyst Energy (DC) MWh	Measured Energy (DC) MWh	PVSyst Energy (AC) MWh	NREL Energyg(AC)d MWh	Measured Energy (AC) MWh
January	1430	1522.570	1407	1,499	1483.92
February	1402	1534.22	1380	1,436	1489.743
March	1526	1655.36	1503	1,592	1602.728
April	1378	1563.15	1356	1,432	1513.477
May	1303	1387.62	1281	1,374	1347.14
June	1096	1121.92	1077	1,204	1093.966
July	1097	1162.94	1077	1,195	1,173
August	1160	1264.717	1139	1,226	1233.227
September	1205	1183.193	1185	1,235	1153.257
October	1165	1518.9	1145	1,253	1477.769
November	1125	1428.99	1106	1,274	1390.355
December	1298	1361.44	1277	1,415	1327.466

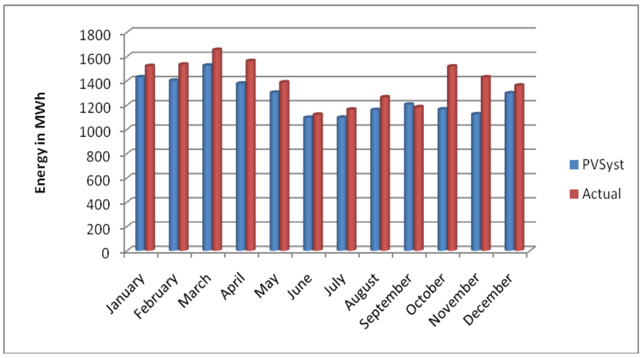

Chart -1: Comparison of PVSyst and actual energy (DC) generation Month wise during year 2016

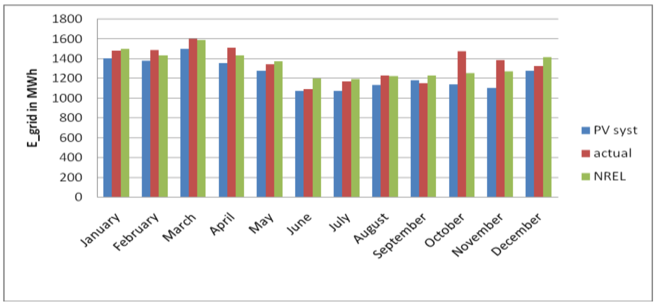

Chart -2: Comparison of PVSyst, PVWatts calculator and actual energy (AC) generation month wise during year 2016

Table -4: Monthly Output energy during year 2016 and also PVSyst and NREL software energy output.

Months	PVSyst Irradiation kWh/m² /day	Measured Irradiation kWh/m² /day	NREL Irradiation kWh/m² /day	PVSyst Temperature ⁰C	Measured Temperature ⁰C
January	6.32	6.32	6.6	21.55	28.88
February	6.34	5.01	7.17	23.75	32.82
March	7	5.32	7.33	26.34	36.05
April	6.26	5.45	6.8	26.94	37.57
May	5.8	4.71	6.06	26.44	29.06
June	4.73	3.81	5.32	24.35	25.87
July	4.72	3.87	5.07	23.35	24.84
August	4.993	4.16	5.22	23.05	25.15
September	5.23	3.96	5.49	23.45	25.35
October	5.086	4.72	5.42	22.85	25.98
November	4.91	4.49	5.74	21.85	27.03
December	5.6	4.01	6.11	20.66	23.87
average	5.99	4.37	6.11	27.05	28.53

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

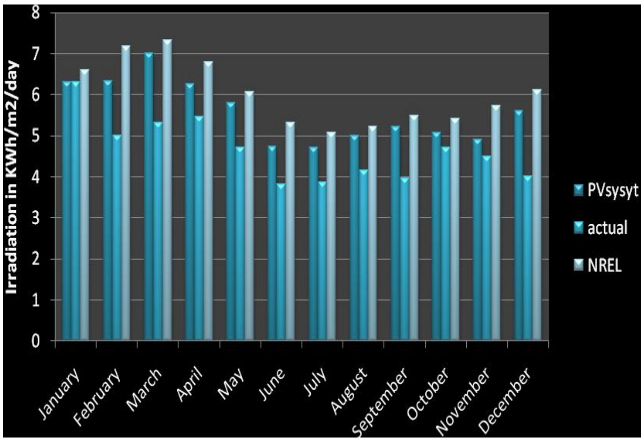

Chart -3: comparison of PVSyst, PVWatts calculator and actual Irradiance data month wise during year 2016

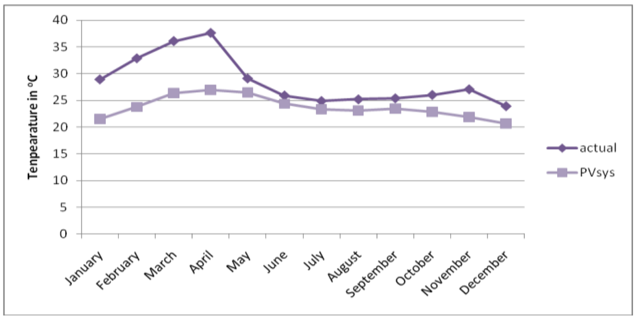

Chart -4: comparison of PVSyst and actual temperature month wise during year 2016

Table -5: Monthly system, PVSyst and NREL software Efficiency and CUF during year 2016 and

Months	Efficiency system in %	Efficiency system in %(PVSyst)	CUF in % (from data)	CUF In % (PVSyst)
January	14.21	12.2	19.95	16.06
February	13.46	11.96	21.4	15.75
March	13.78	11.78	21.54	17.15
April	13.75	11.84	21.04	15.47
May	13.34	12	18.11	14.62
June	13.82	12.3	15.19	12.29
July	13.81	12.37	15.77	12.29
August	13.82	12.4	16.58	13.002
September	13.82	12.29	16.02	13.52
October	13.72	12.29	19.89	13.07
November	13.85	12.3	19.31	12.62
December	13.88	12.45	17.84	14.577

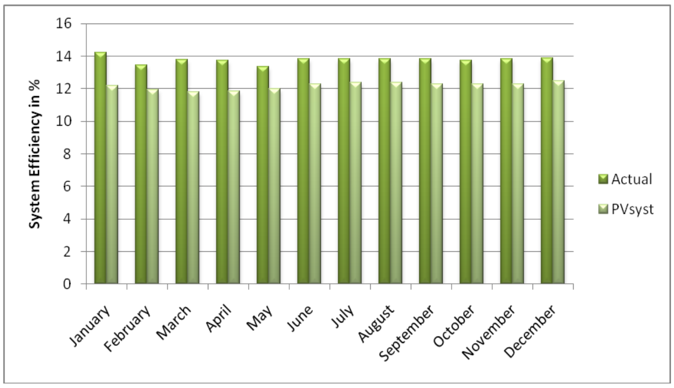

Chart -5: comparison of PVSyst and actual efficiency month wise during year 2016

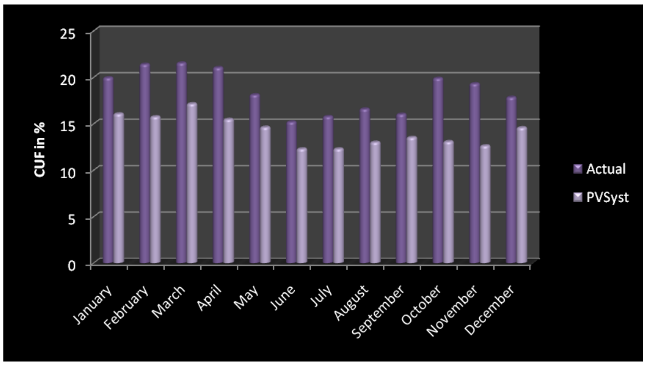

Chart -6: comparison of PVSyst and actual CUF month wise during year 2016

6. CONCLUSIONS

1. Energy generation of 34460 to 53400 KWhr per day at average of 44600 KWhr whole the year is observed which adversely affect the growth of the country because of the following reasons
2. During sunny days where the hydro fails and the fossil fuels are gaining the price solar PV plant benefits the human kind with electricity during almost all the seasons in India.
3. By International standards in generation of 1KWhr of energy the amount of coal used is 1kg and wasted water is 3.3 litres. Whereas in this plant we are generating 44600 KWhr of energy per day hence 44.6 tonnes of coal is being saved and 147 metric tonnes of water every day.
4. And also in Conventional way of generation i.e. coal generation plants 1kWhr generation produces 1kg of co_2 and 1kg of other GHG .this plant is helping in reducing 44 tonnes of co_2 and same amount of GHG everyday these dangerous gasses into the environment.
5. Payback period for solar power plant will be below 15 years while it has capacity to generate for 25 years hence for the rest of 10 years energy can be used free of cost. I.e. revenue.

6. Every country should have abundant, affordable and reliable energy.
7. During the past few years, renewable energy sources have received greater attention and considerable inputs have been given to develop efficient energy conversion and utilization techniques.
8. Energy Conservation is the Best Reservation for the Future Generation.
   Today's clean environment is tomorrow's safe environment and today's world is yesterday's creation, tomorrow's world will be today's conservation.
9. It is the responsibility of the society to conserve energy, energy resources and protect the environment and SAVE THE MOTHER LAND.

Result:

It's clear that the PVSyst shows the smaller energy output when compared with Actual generation. Whereas grid side output NREL shows more accurate values compared with the PVSyst software

Actual Irradiation values are more nearer to PVSYs software hence it is more accurate than the NREL software and measured temperature is greater than the PVSyst output temperature.

Efficiency of the system remains almost same during all the months. And PVSyst efficiency is lesser when compared with the actual SCADA output.

Actual Coefficient of Utilization Factor is greater than PVSyst CUF during the year 2016.February March and April have the highest CUF compare rest of the months. The Actual CUF is varies almost sinusoidal.

ACKNOWLEDGEMENT

It is my pleasure to express my sincere gratitude to my guides Mrs. SOUMYA RANI M, Assistant Professor in the Department of Electrical and Electronics Engineering and Dr. H. NAGANAGOUDA, Director, National Training Centre for Solar Technology, KPCL, Bangalore, for his help, suggestion, co-operation and valuable guidance in preparing the industrial training report.

I wish to express my sincere gratitude to Dr. SHASHIKANTH KARINKA, Head of the department of Mechanical Engineering for his guidance, suggestion, moral support and encouragement.

I would like to thank Branch coordinator Prof. NARASIMHA BAILKERI, Assoc. Professor, for encouragement to complete the project work.

I am grateful to Dr. Niranjan N Chiplunker, Principal, NMAM Institute of Technology, Nitte, for having supported me in my academic endeavors.
And my special credits to the number of trees felled to print this work.

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