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DESIGN AND SIZING OF A GRID CONNECTED SOLAR PV SYSTEM

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ABSTRACT

To shape aoptimized pathway for development and utilization of solar energy the present project utilizes PVSYST; a software used for sizing of Grid connected, stand alone and solar pumps for any particular location. This paper analyzes and designs a photovoltaic (PV) array and defines inverter sizes for a grid-connected PV system. The Proposed site is in Nalgonda, Telangana with of Latitude17°20' 'N ,and Longitude: 7 8° 72' E. Various inputs like the load ,peak power, module voltage, global irradianceand tilt angle are given ,and a detailed report on the losses of PV array as well as the inverter are obtained.

I. INTRODUCTION

The trend for India's energy consumption out of conventional sources is found to increase with increased industrialization and civilization aspects of the society. The estimated electricity consumption increased from 4,11,887GWh during 2005-06 to 882,592GWh during 2013-14, showing a cumulative average growth rate (CAGR) of 8.84 %. The increase in electricity consumption is 7.07% from 2012-13 (824,301GWh) to 2013-14 (882,592 GWh) Of the total consumption of electricity in 2013-14, industry sector accounted for the largest share (43.83%), followed by domestic (22.46%), agriculture (18.03%) and commercial sectors (8.72%) . The electricity consumption in Industry sector and commercial sector has increased at a much faster pace compared to other sectors during 2005-06 to 2013-14 with CAGRs of 10.97% and 8.82% respectively [1].Thus the increasing demand and scarcity in conventional sources has triggered the scientist to pave way for the development of research in the field of renewable energy sources especially solar energy.

In a Grid Connected PV (GCPV) system the generated electricity is self-consumed and the excess could be fed to Grid. The (GCVP) projects are envisaged to mitigate diesel consumption when the buildings are operating with diesel generator backup. If the grid power is continuous, the solar power generated will be utilized along with the grid power and the proportionate amount of grid power usage will be reduced. During minimum load periods (e.g. during weekends and holidays), the excess power generated from solar systems could be fed to grid. In 2014, PV-generated power totaled 35.2 TWh that accounts to approximately 6.9 percent of Germany's net electricity consumption[2].However the amount of irradiance received is 2.62 kWh/m2/day (it varies from 0.67 to 4.62 kWh/m2/day)[3]. The amount of Irradiance received by India is 5.5 kWh/m2/day with about 300 sun days [4].Thus it shows that the Indian solar market possess huge potential for exploitation. Jawaharlal Nehru

National Solar mission, a project launched by Government of India (GOI) has set the ambitious target of deploying 20,000 MW of grid connected solar power by 2022 is aimed at reducing the cost of solar power generation in the country .One of the objectives of Jawaharlal Nehru National Solar mission is to utilize the large area roof top installations [5].

The array size, inverter sizing and transformer capacity are the key factors in designing a solar PV system. AmalMarrekchi studies the Ways to size the inverter and made a practical guide to connect it to the grid [6]. The feasibility of a Grid connected solar PV system in south India was studied by Sundaram and Sarath [7]. Optimal sizing of grid-connected photovoltaic energy system was studied by Makbul A.M. Ramli [8].

II. PVSYST

In SouthAfrica D. Okello et al in their study [9] using PVSYSTtool, theyfound good approximation by the software to measured energy output for a 3.2 kW_p system. In light of this the authors seemed it proper to select the particular software for design and optimization of the system for the location. PVSYST toolwas developed by AndréMermoud[10] is used for the study, sizing and data analysis of complete PV systems**.** It deals in grid-connected, stand-alone, andpumping PV systems. The softwareincludes extensive met data and PV systems, components databases, as well as general solar energy tool.

III. LOCATION DETAILS AND METEOROLOGICAL DATA FOR THE PROPOSED LOCATION

In PVSYST, the solar resource input can be the coordinates of the location .Based on location coordinates, data can be accessed from NASA website dealing withMeteorological data [11]. The averagesolar radiation in proposed site i.e inNalagonda which is at latitude $17^o.20'$ North andlongitude$78^o.72'$Eastis 5.17 kW/m^2 day. Solar irradiance is high (above the average) from March to May, with a peak in the month of April, while solar irradiance (below the average) from June to December.Fig 1.Shows the solar radiation data at the proposed location which is used in the simulation. The software does not take into consideration the wind velocity.

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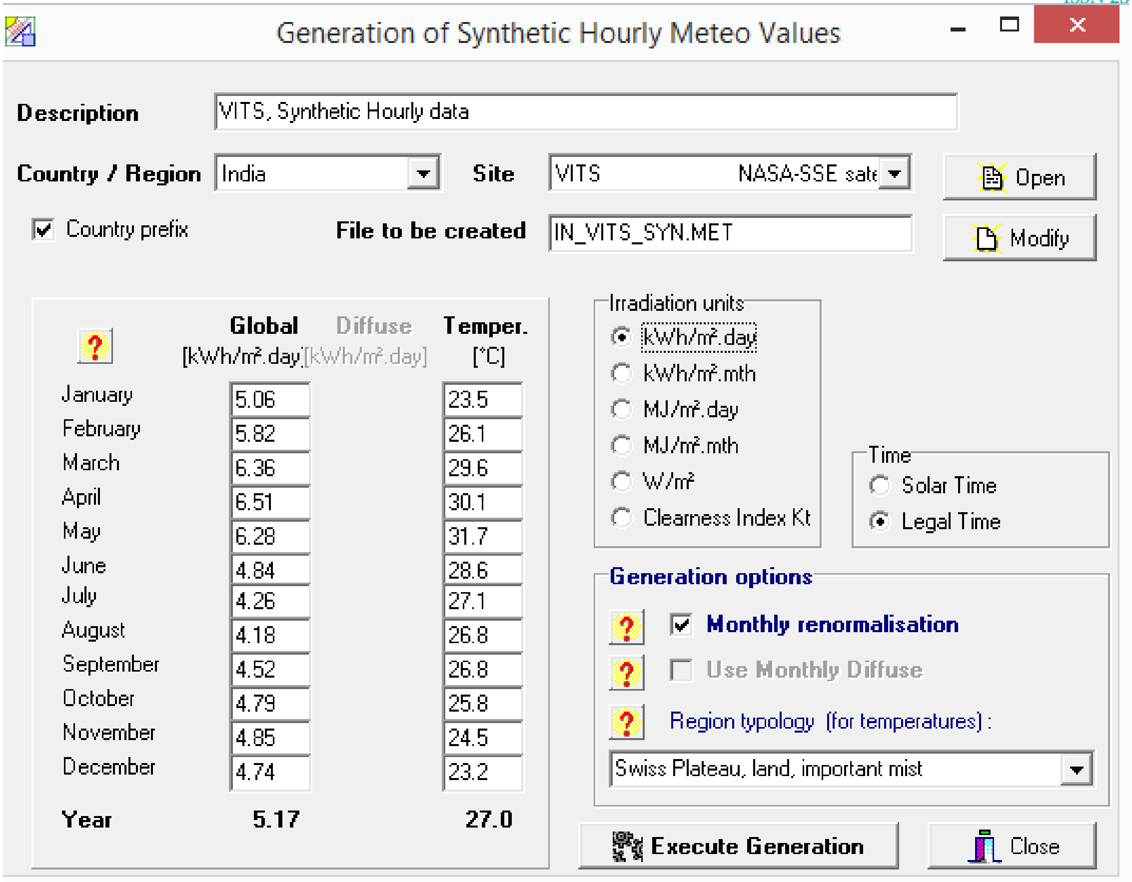

Fig 1 Hourly Meteorological data for the proposed site

IV. LOAD PROFILE

According to the policy of government of India the grid connected solar PV system is supposed to be designed only for 80% of the capacity of the transformer present at the location. The proposed site has a transformer capacity of 500 kW peak. Therefore the maximum capacity of the proposed grid connected system is selected to be 400 kW.

V. DESIGN SPECIFICATION

In this design the system is a grid connected solar PV system which consists of a PV panel, inverter, grid and the load as shown in fig 2. This system is selected to reduce the cost of the whole system by avoiding battery back-up. When the battery back-up capacity is excluded, the cost of the whole system decreases by around 40 to 50% depending on the type of batteries used and the capacity required.

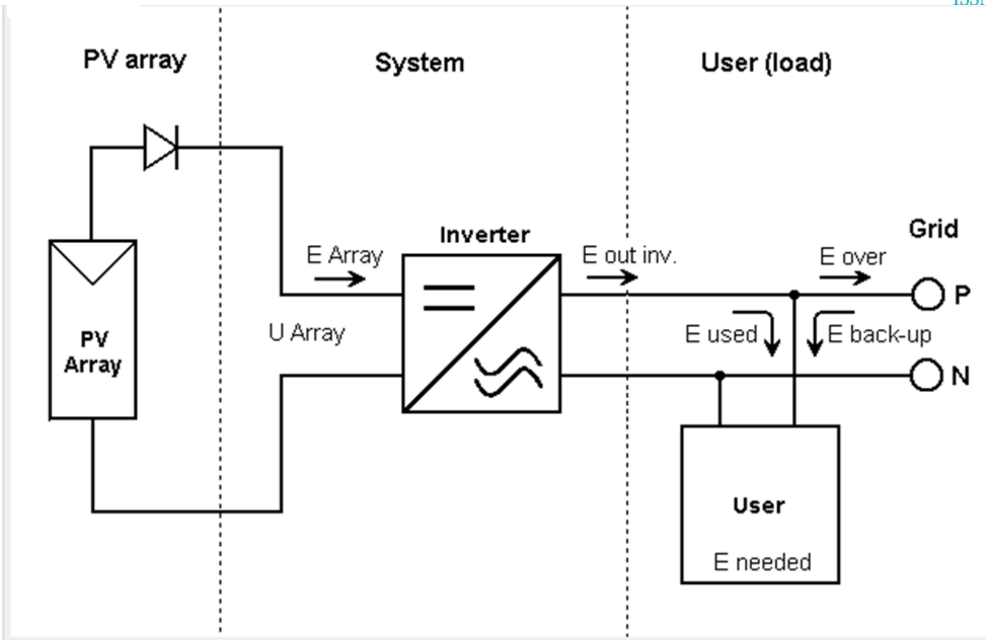

Fig 2. Schematic Layout of a Grid Connected Solar PV System

5.1. PV Panels and Array

The size of PV array is derived from the available area, the amount of solar radiation and the load profile. The peak load value for each panel can be decided keeping in mind the area and the output voltage required. The PVsize adjustment ensures that the variation in load demand in a year is well catered for. The manufacturer can then beselected based on the peak load and the minimum voltage .In PVSYST the panel can be selected according to the manufacturer, technology and power.

5.2. Inverter

The PV arrays produce direct current (DC) at a voltage, which depends on the specific design and the solar radiation. The DC power then runs to an inverter, which converts it into standard AC voltage. Inverters commonly used in large scale applications are central inverters that offer easy installation and high efficiency. The inverter operates on the nominal power, and the nominal power (P_{rom}) of a inverter is defined as the output power i.e. theratio of nominal power in AC to the Efficiency of the inverter .the value is defined at STC the value it is usually of the order of 1.0 to 1.1[10].

VI. SIMULATION RESULTS

6.1Design of PV Panel

PVSYST offers a database of PV arrays based on power, the technology and the manufacturer. The electrical parameters (maximum power point and temperature coefficient), efficiency and the fill factor are considered while selecting a PV array. The present system has an available area of 3319m^2 and the maximum capacity of the system is 400 kW. The maximum watt peak of a particular panel is considered. Simulations were run for a 250Wppanel (readily available in market) at Standard Test Conditions(STC)and Nominal Operating Collector Temperature (NOTC) of 45^{o}C,free mounted modules with air circulation. The losses are the major consideration while selecting a panel and the detailed losses of the selected panel for the proposed site are shown in the table 1

Type of loss	Percentage loss
Due to Irradiance	3.8
Due to Temperature	8.8
Module quality	0.9
Module array mismatch	2.2
Ohmic wiring loss	1.0

Table 1. Detailed PV array Losses.

The temperature coefficient of the selected model is 0.41%/^{o}C rise in temperature. The V_{mpp}andV_{oc} at 60^{o}C and -10^{o}c are 26.9V and 42.2V respectively. Therefore for the proposed site the no of modules needed is 1600.The I/V characteristics of the selected module are shown in fig 3.

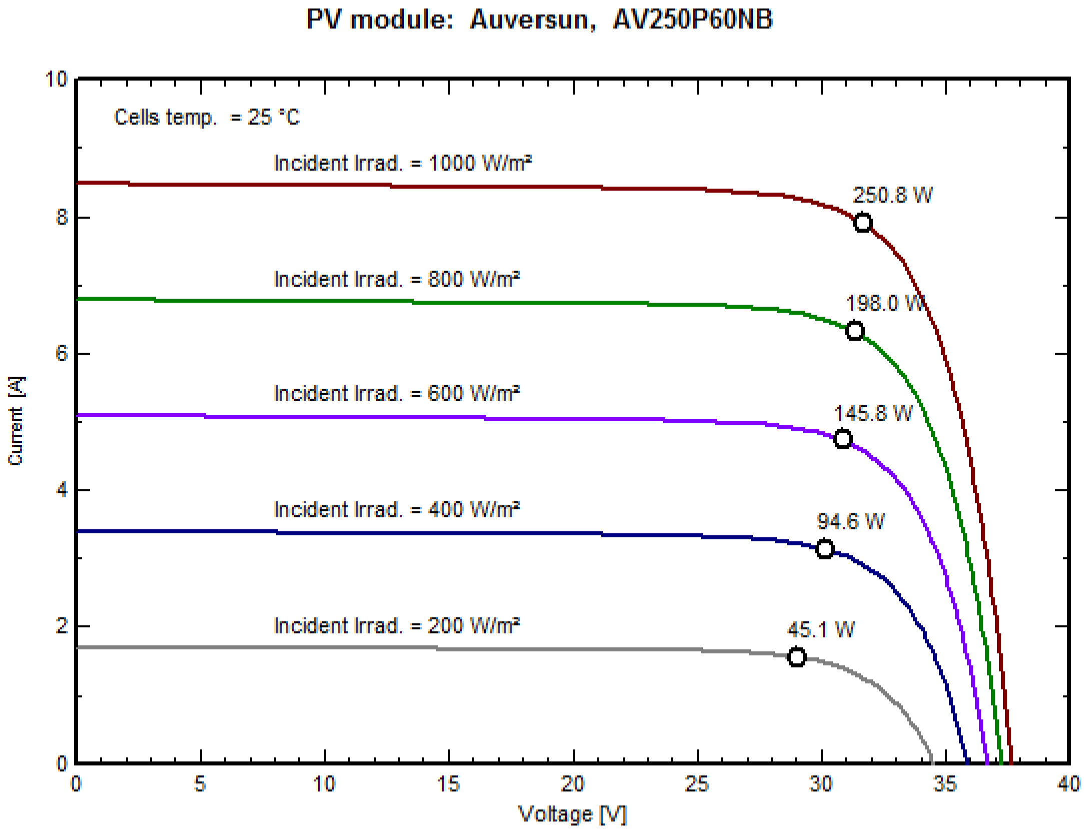

Figure 3. I/V characteristics at different Irradiance level

6.2 Design of Inverter

Since optimization technique is focused on decreasing the losses, the mismatch losses for the inverter are to be reduced keeping in mind the cost of the system. For a 50kW inverter the mismatch losses are high compared to that of a less nominal voltage. Therefore in this study 20kW inverters are used with the operating voltage of 490-800V.the frequency of the inverter is 50/60Hz, and it has a maximum efficiency of 98.7%.the efficiency curve as a function of the output is shown in the fig 4.however since the number of inverters is more the losses in operation (mismatch loses) are minimized and are only 1.6% of the total losses. The inverter output distribution is shown in figure 5, which gives the information of the P_{nom} values.

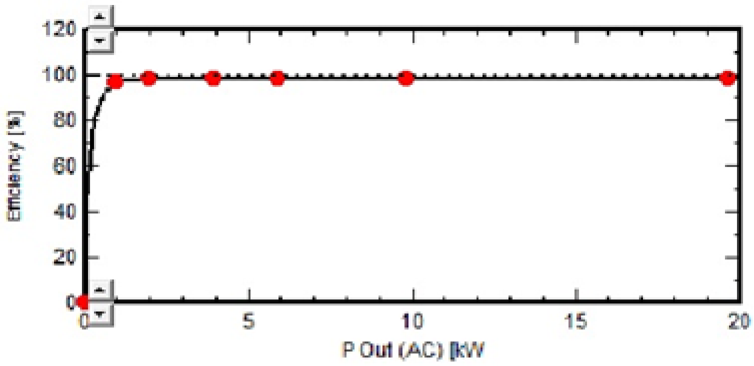

Figure 4. Efficiency CURVE of the INVERTER

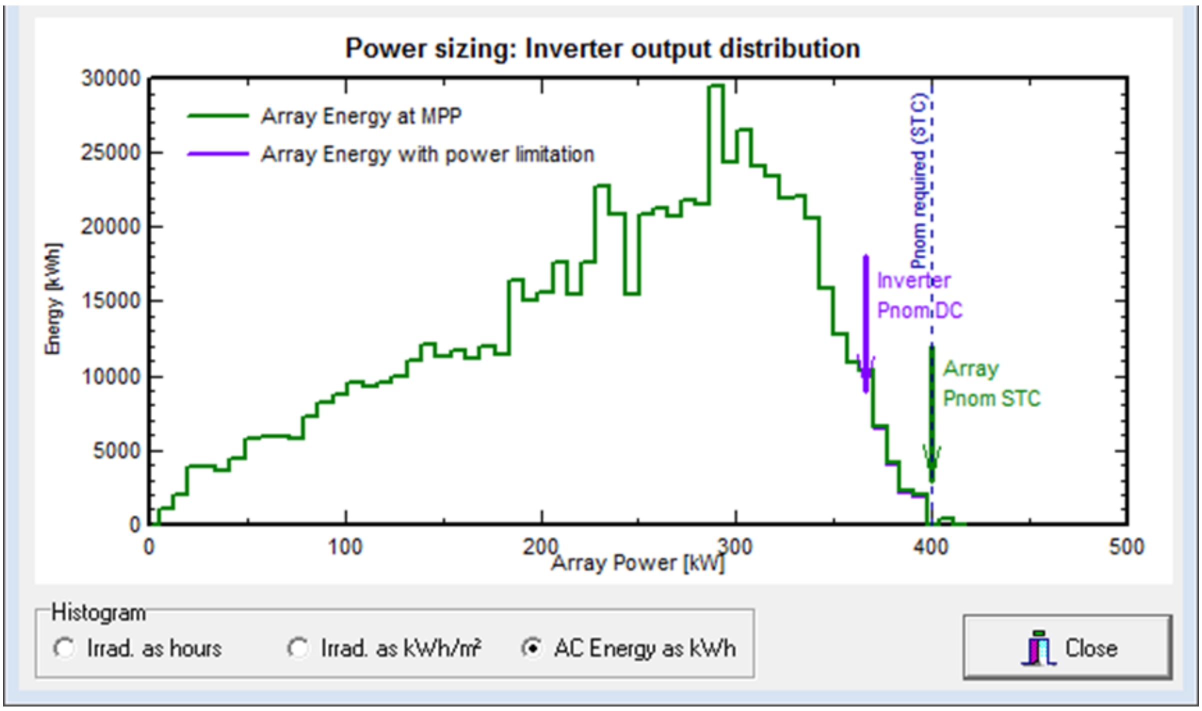

Fig 5. Inverter Output Distribution

6.3 Sizing of PV System

The number of strings and the number of modules in each string is designed after the inverter sizing is computed. The sizing should be in such a way that the P_{nom} ratio should be of the order 0.8 to 1.20 and the overload losses are minimized. Therefore for number of modules are 1600 and the number of modules in each string should be in between 19 to 24(inverter capacity). Similarly, corresponding to it the number of strings varies with the no of modules in each string selected. The sizing is done is such a way that the planned output power is obtained. Fig 6 represents the layout of the system. The number of modules in each string is 20 and there are 80 similar strings. Since the inverter capacity is 20kW only 4 strings are connectedto inverter and they form a subsystem. 20 such subsystems are interconnected for attaining the desired load.

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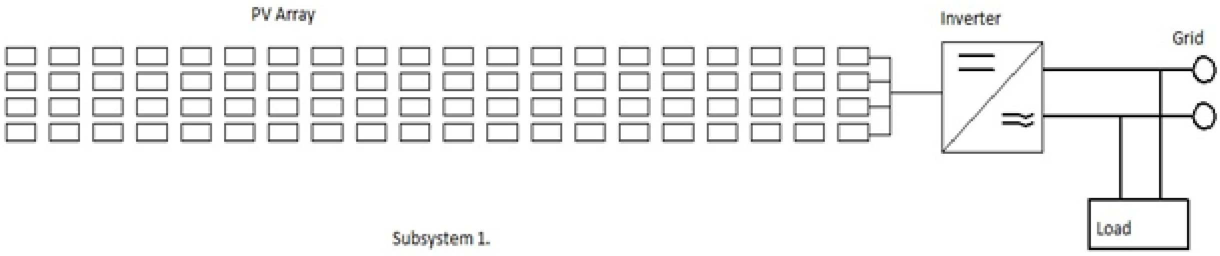

Fig 6. Diagrammatic Representation of a Subsystem

VII. RESULTS

The optimum PV array and inverter sizes for a grid connected PV system have been obtained for defined load .The losses have been decreased by different combinations of strings, modules and also the inverter capacity. The detailed losses have been explained in fig 7 and fig 8. However the Energy injected into the grid per year was found to be about 640MWh with an array virtual energy of 650MWh. Fig 9 shows the effective energy at output of array , percentage efficiency of the array andpercentage efficiency of the system, which was found to be 650407 kWh , 12.59% and 12.39% respectively.

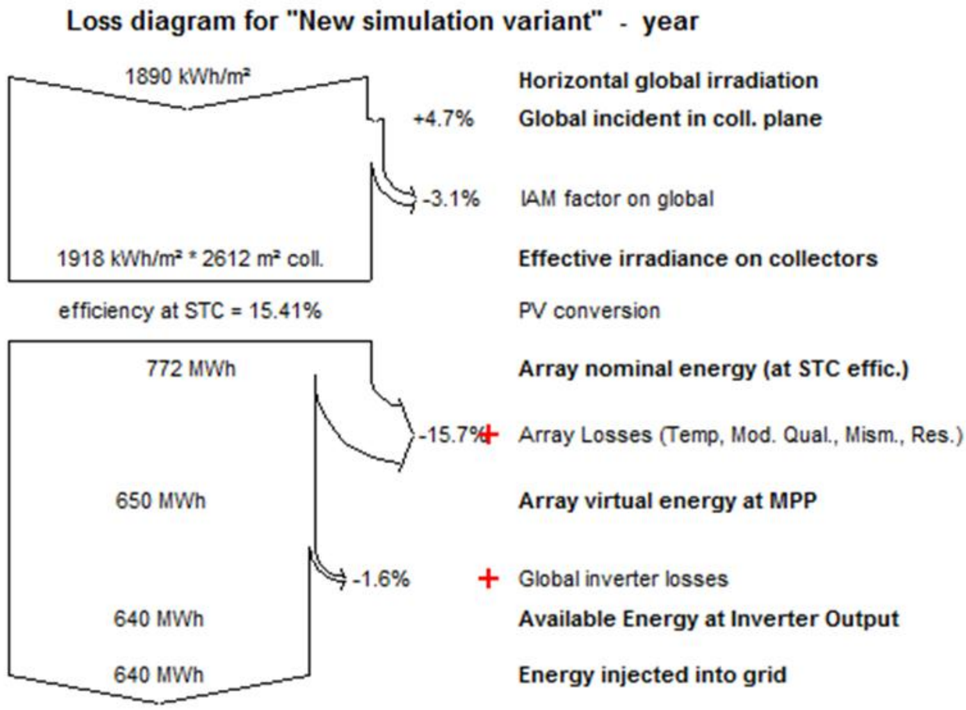

Fig 7.Yearly Loss diagram of PV array and Inverter

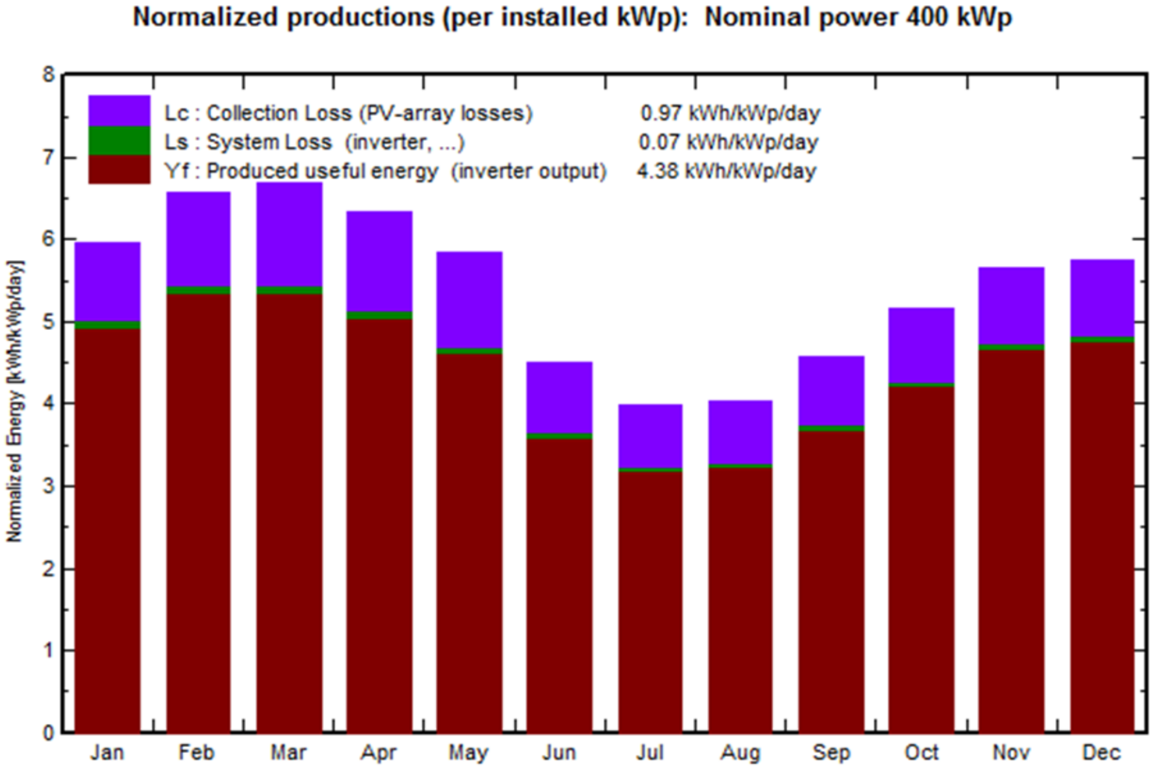

Fig 8. Monthly Loss Diagram of PV Array and Inverter

New simulation variant

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	%	%
January	156.9	23.52	185.2	180.1	62222	61223	12.86	12.66
February	163.0	26.12	184.2	179.1	61000	60008	12.68	12.47
March	197.2	29.61	207.2	201.5	67498	66429	12.47	12.27
April	195.3	30.06	190.4	184.5	61664	60675	12.40	12.20
May	194.7	31.70	181.3	175.5	58197	57258	12.29	12.09
June	145.2	28.65	135.4	130.4	43832	43126	12.39	12.20
July	132.1	27.06	123.9	119.3	40141	39497	12.40	12.20
August	129.6	26.77	125.2	120.8	40836	40198	12.49	12.29
September	135.6	26.82	137.1	132.8	44932	44218	12.54	12.34
October	148.5	25.79	160.2	155.6	53066	52238	12.68	12.48
November	145.5	24.49	169.9	165.0	56940	56046	12.83	12.63
December	146.9	23.16	178.3	173.1	60080	59148	12.90	12.70
Year	1890.4	26.98	1978.4	1917.7	650407	640066	12.59	12.39

Fig 9. Simulation Results

VII. CONCLUSION

For the renewable energy system particularly solar energy system the major factor in decreasing the cost and optimally sizing the system. Various methods are being utilized by different organizations in planning and sizing the grid-connected PV systems. In this paper optimal size of PV, inverter of a grid-connected PV system for proposed site in Nalagonda has been investigated by using PVSYST as a software tool.

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