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Performance Analysis of 33KW Grid Connected Solar Roof Top Power Plant

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Abstract*: Solar Roof tops are being progressively used worldwide now a days to install solar panels to generate electricity. One such step has been taken by S.R.K.R Engineering College to generate power through solar roof tops by installing a 33KWp On-grid solar power system (Latitude 16.54° N and Longitude 81.50° E) during April-2016. This grid connected PV system is installed at an area of 345 sq. m and the PV modules are tilted at an angle of 18° on the top of a 3 staired building. This paper analyses the Performance of a 33KWp On-grid photovoltaic system which is monitored between Jan-2019 to Dec-2019. Some part of electricity generated by the system is consumed by the college and the remaining power was fed in to the state grid. The tariff for the grid connected system is based on the energy consumed from the grid and the energy supplied in to the grid. The data is collected from the Data-logger of the inverter which is having an IP address. This data is collected according to the IEC protocol which suggests to collect the data for every 15 minutes. The data is collected from the inverter in this format and is stored as a csv file every day. This data along with the meteorological data collected from the coordinates of the site are analyzed by using pvsyst simulation software. The performance of this system is found for the third year in operation. . The analysis of the PV system has been done to enumerate its performance at each and every component and thereby develop solution to mitigate the problems. The different parameters including efficiencies of panels, inverter, array's initial yield, final array yield, and the performance ratio of PV system are analyzed.

***Keywords*: Grid connected PV system, performance analysis, Pvsyst software, Roof top**

I. INTRODUCTION

Global temperatures are increasing day by day with the emission of fossil fuels in to the atmosphere, with the increase in the global temperatures the ozone layer depletion is taking place. The steep increase in the emission of fossil fuels from the Earth's atmosphere by combustion of natural resources is the ultimate reason for the increase in Global temperatures. The natural resources like coal, gas and oils are decreasing year by year with this rapid pace of development activities which require electricity as the major game changer in all the fields. So there is an immediate necessity to reduce the emission of these fossil fuels in to the atmosphere. One of the major causes for this increase in the temperature are power generating plants which uses coal, gas, diesel etc., as a fuel for converting thermal energy in to electrical energy. By burning these fuels at high temperatures the flue gases are emitted from the boiler of thermal plant in to the atmosphere. In order to protect the earth's atmosphere the Non-conventional Power generating plants which uses wind, solar, tides, geo-waste etc., are used which uses inexhaustible sources of the atmosphere for the generation of power.

Ministry of new and renewable energy (MNRE) has launched the National solar mission to encourage the Renewable energy production in the country by giving away 30 % subsidy for the people who are willing to install the solar power plant. This Mission is targeted to install 175 GW of capacity from the renewables by 2022. Based on this mission different state governments are encouraging the commercial and also the domestic consumers to install the solar plants at their places. The other initiative taken by the state is by encouraging the installation of Grid-connected solar power plants. In which the consumers sells the power to the utilities by using the Net metering policy. The net metering policy decides the cost for unit of electricity fed in to the grid. Based on this policy the customers can sell the power to the grid during day times and can consume the power from the grid during the nights. The difference between the two is the cost saved by installing the on-grid system. Solar Roof tops are very economical when compared to other forms of solar systems as it does not include the cost of purchasing land, existing rooftops can be utilized to install solar system which saves a larger economic burden and capital investment which are the major factors in the planning of on grid systems.

II. ON GRID SYSTEM

The on grid system is one of the type of PV system in which the storage of power is not available. The power generated is directly utilized or it is directly fed in to the grid. Because it is connected in series with the Grid it requires an extra protection from shock hazards. The inverter in the Grid connected system is not the same as it is in the off grid or hybrid systems, the On grid inverter is provided with anti-islanding mechanism which does not allow power to flow back to grid from the PV system while the grid is in off state or maintenance works are being taken place because of faults. This Anti-islanding mechanism stops the power flowing to the grid from the PV system while the grid is in maintenance and it provides protection against the shock to the persons working on the maintenance works.

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The scheme discussed above is for providing protection for the grid side while the customer or the owner of the On-grid system also has some protection equipment that are mandatorily connected in order to protect the expensive components like the inverter, PV modules and especially the appliances on the consumer end. For providing this protection the DCDB and ACDB are used before and after the Inverter as shown in Fig.1. The DCDB is connected in series to the PV modules. The DCDB consists of SPD, MCB and the Fuse. It is connected in series to protect the inverter from high voltages and high currents that occur due to surges or faults before the inverter. The DCDB suppresses these abrupt changes in voltage and currents and provide flaw less dc power in to the inverter. The ACDB is connected in series to the inverter from which the consumers take AC output as shown in Fig.1. ACDB protects the consumer's appliances from the faults that are occurred in the inverter. In addition to these, surge arresters are used to protect the PV Modules from the surges. As the installation of grid connected PV system involves a huge amount of capital investment these are the various protection schemes that are adopted by the developers to protect the equipment, apart from the protection schemes that are maintained by the Utility.

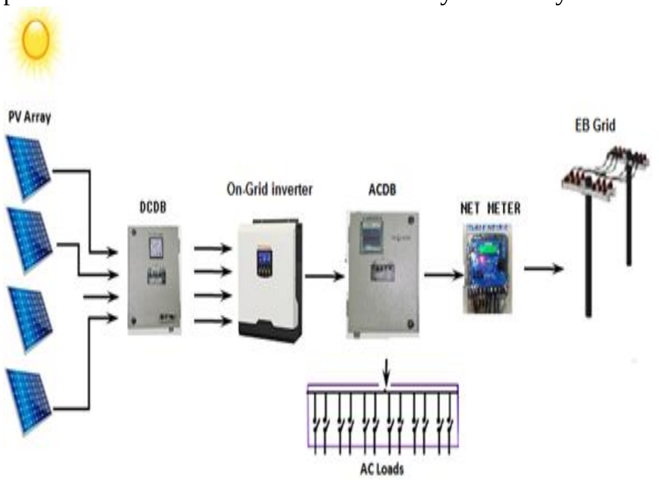


Fig. 1. Grid connected PV System

III. METHODOLOGY

Andhra Pradesh is a state that is located in the southern part of India. It is having moderate atmospheric conditions that are favorable for the installation of PV systems unlike some of the northern states where temperatures are not moderate to install the PV systems. There are different geographical locations in A.P where there is no comparison between one place to the other. So this paper is done in this aspect to analyze the performance of the On-grid PV system at the location. The performance of the present system is analyzed using the pvsyst software. To start with the different data corresponding to the site are collected they are

1. Meteorological data corresponding to the site.
2. Sun chart of the site.
3. Layout of the plant.
4. Ratings of PV Module used.
5. Rating of the Inverter.
6. Panel orientation at the site etc.,

The performance of 33kw power system is analyzed by collection of data corresponding to the co-ordinates of the site based on the latitude and longitude, the sun chart corresponding to the site is extracted and the sun path has been analyzed based on the 3-D plotting at the site as shown in Fig. 3. The number of sun hours per day has been calculated and the shadow analysis for the plant is done and it shows that there is no effect of shadows from nearby buildings, trees etc., for plant during 9 A.M to 3 P.M as maximum power generation from PV is done during this period. The number of sun hours per day is found to be 5.2 kwh/day i.e., per 1KW plant the installed system generates approximately 5KW of power in a day. Therefore for 33kw plant it can generate approximately 165kwh in a day. Later, the meteorological data corresponding to the location has been collected.

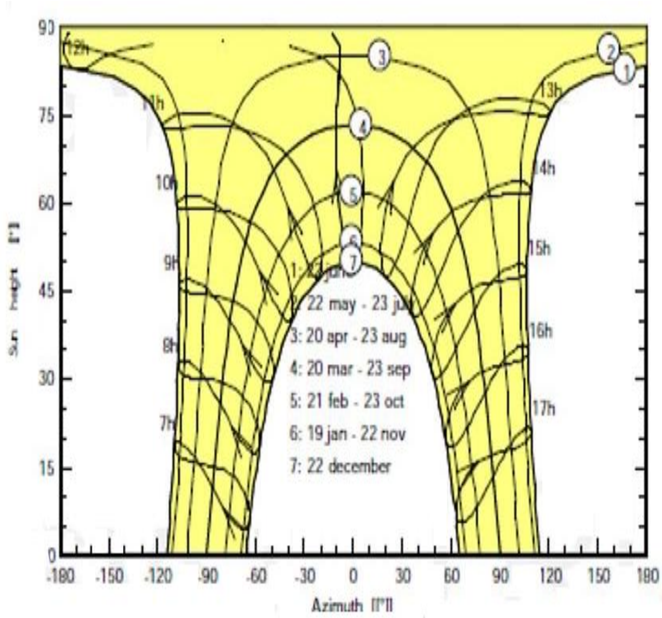


Fig. 2. Sun chart of the site

Fig.3. Sun path at the site (source: Google)

After necessary data is collected the data is analyzed using the pvsyst software. The pvsyst is a software that is used to design, study, simulation and data analysis of entire PV systems. In this software all the data that was collected earlier corresponding to site has been given as an input.

Besides the manufacturer's data corresponding to the modules and inverter has been fed to the simulation software. This data is compared with the data collected by the data logger of the inverter and is found to be correct. Based on this data the daily power generation and the monthly power generation from the PV system were plotted and are shown in the Fig.4 and Fig.5 respectively.

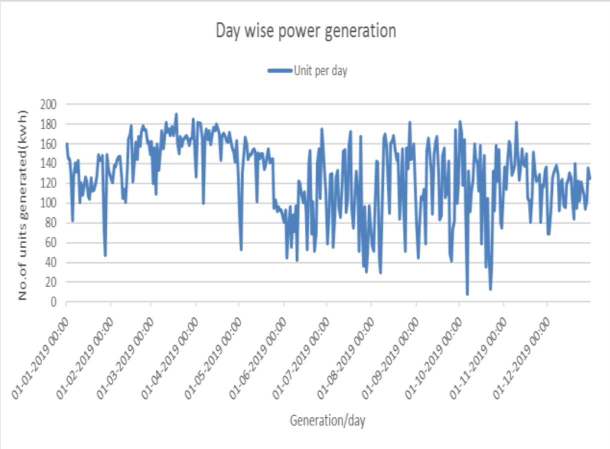


Fig. 4.Day wise Power generation variation

After collecting all the necessary data required for evaluating the performance of the plant we simulate the efficiencies of panels, inverter, array's initial yield, final array yield, and the performance ratio of the 33 KW grid connected PV system.

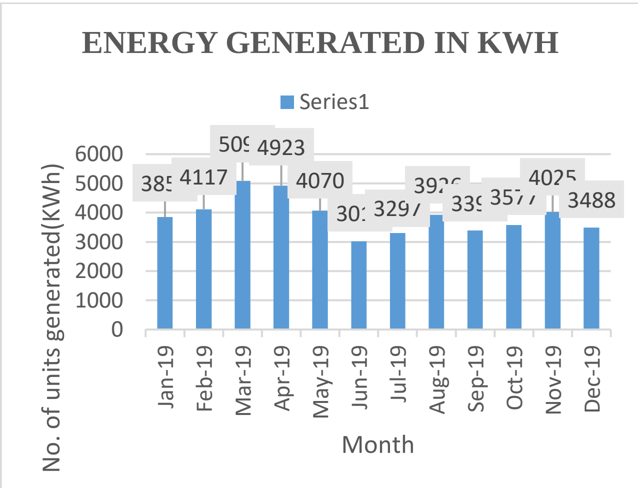
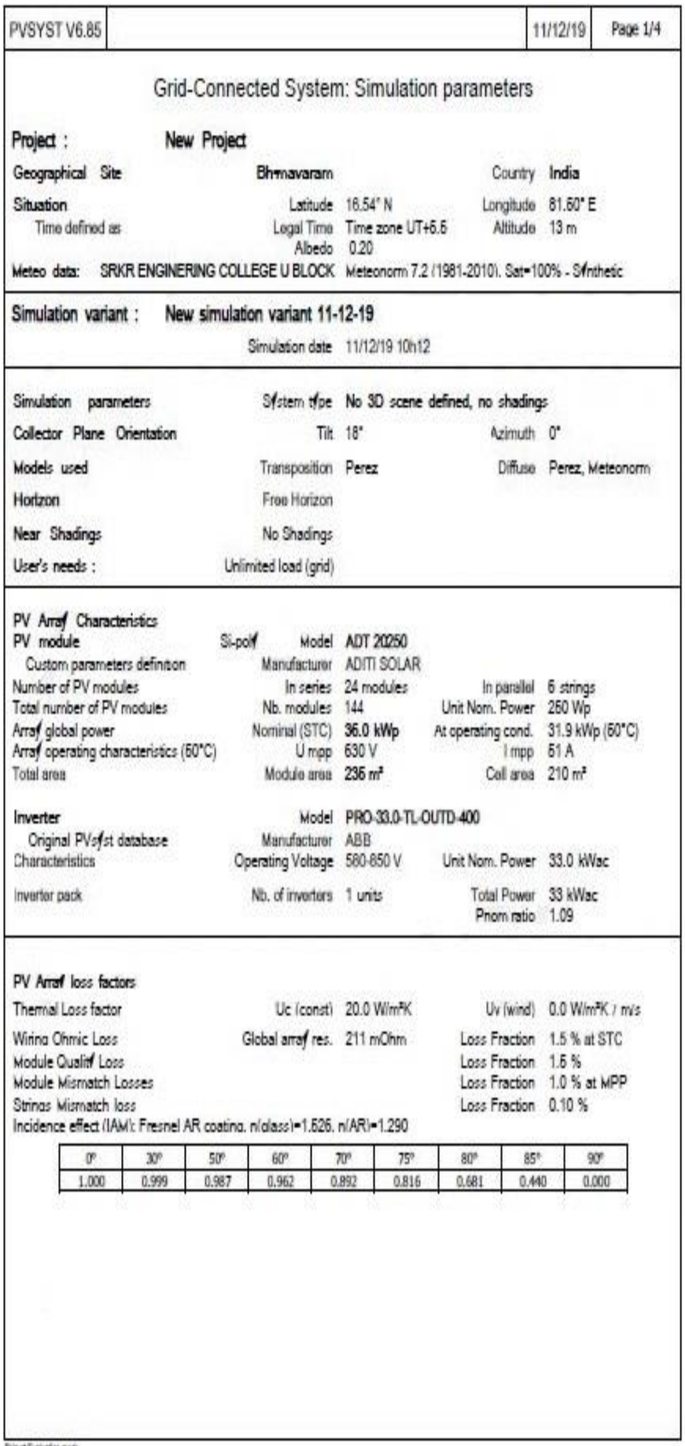


Fig. 5. Monthly Power generation

IV. PERFORMANCE EVALUATION

The simulation result of the 33Kwp system by using simulation software for the period of 1-1-19 to 31-12-19 is given below. The albedo is considered to be 0.20 in this study. The synthetic hourly data generation is done by using Meteonorm 7.2. The simulation is done for 144 modules out of which 24 modules are in series and 6 strings in parallel.

There is no shadings and no 3d scenes are defined. The simulation is done based on modules and inverter taking in to consideration of the losses associated with it. These losses are defined as per the data sheets of the panel and the inverter. The simulation report that was generated after the simulation is shown in the Fig.6.



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Grid-Connected System: Simulation parameters

Project :	New Project				
Geographical Site		Bhimavaram		Country	India
Situation		Latitude	16.54° N	Longitude	81.60° E
Time defined as		Legal Time	Time zone UT+5.5	Altitude	13 m
		Albedo	0.20		
Meteo data:	SRKR ENGINERING COLLEGE U BLOCK		Meteonorm 7.2 (1981-2010), Sat=100% - Synthetic		

Simulation variant :	New simulation variant 11-12-19		
	Simulation date	11/12/19 10h12	

Simulation parameters	System type	No 3D scene defined, no shadings		
Collector Plane Orientation	Tilt	18°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			
User's needs :	Unlimited load (grid)			

PV Array Characteristics				
PV module	Si-poly Model	ADT 20250		
Custom parameters definition	Manufacturer	ADITI SOLAR		
Number of PV modules	In series	24 modules	In parallel	6 strings
Total number of PV modules	Nb. modules	144	Unit Nom. Power	250 Wp
Array global power	Nominal (STC)	36.0 kWp	At operating cond.	31.9 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	51 A
Total area	Module area	236 m²	Cell area	210 m²
Inverter	Model	PRO-33.0-TL-OUTD-400		
Original PVsyst database	Manufacturer	ABB		
Characteristics	Operating Voltage	580-850 V	Unit Nom. Power	33.0 kWac
Inverter pack	Nb. of inverters	1 units	Total Power	33 kWac
			Pnom ratio	1.09

PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	211 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	1.5 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): Fresnel AR coating, n(glass)=1.526, n(AR)=1.290

0°	30°	50°	60°	70°	75°	80°	85°	90°
1.000	0.999	0.987	0.962	0.892	0.816	0.681	0.440	0.000

Fig. 6. Simulation report of the plant

Table- I: Meteo data from Meteonorm 7.2

Month	GLOBHOR Kwh/m²	DIFFHOR Kwh/m²	T AMB °C	GLOBINC Kwh/m²	GLOBEFF Kwh/m²	EARRAY Mwh	EGRID Mwh	P.R
JAN	*144.1*	*56.20*	*23.31*	*169.8*	*166.1*	*4.785*	*4.688*	*0.767*
FEB	*140.9*	*63.36*	*25.31*	*157.6*	*153.7*	*4.374*	*4.288*	*0.756*
MAR	*164.6*	*79.54*	*28.23*	*172.2*	*167.7*	*4.659*	*4.566*	*0.736*
APR	*165.7*	*88.51*	*30.61*	*163.0*	*158.3*	*4.357*	*4.272*	*0.728*
MAY	*170.9*	*96.42*	*33.26*	*161.1*	*156.2*	*4.215*	*4.134*	*0.713*
JUN	*140.2*	*91.98*	*31.43*	*130.3*	*126.0*	*3.468*	*3.400*	*0.725*
JUL	*131.9*	*91.21*	*30.37*	*123.8*	*119.7*	*3.324*	*3.256*	*0.731*
AUG	*146.9*	*98.13*	*29.05*	*141.7*	*137.2*	*3.859*	*3.783*	*0.741*
SEP	*137.9*	*78.46*	*28.38*	*139.7*	*135.6*	*3.795*	*3.718*	*0.739*
OCT	*139.6*	*76.43*	*27.47*	*151.1*	*147.1*	*4.150*	*4.066*	*0.48*
NOV	*133.8*	*60.24*	*25.12*	*153.3*	*149.8*	*4.274*	*4.188*	*0.759*
DEC	*136.7*	*61.89*	*23.51*	*162.8*	*159.0*	*4.602*	*4.513*	*0.770*
Year	**1753.2**	**942.38**	**28.02**	**1826.3**	**1776.3**	**49.862**	**48.874**	**0.743**

Legend:

GlobHor	Horizontal global irradiation	GlobEff	Effective global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation	Earray	Effective energy at the output of the array
T_Amb	T amb	Egrid	Energy injected in to grid
GlobInc	Global incident in coll. Plane	PR	performance ratio

Table- II: Comparison table of System Performance.

Reference	Location	Cell type	System size(kWp)	Final yield (kWh/kWp/day)	PV module Efficiency (%)	Inverter Efficiency (%)	Performance ratio (%)
Vasisht et al. (2016)	*India*	*P-Si*	*20*	*4.1*	*13.71*	*–*	*85.00*
Pundir et al. (2016)	*India*	*P-Si*	*18*	*-*	*8.76*	*-*	*63.58*
Kamalapur and Udaykumar (2011)	*India*		*50*	*5.5*	*-*	*89*	*-*
Kumar and Nagarajan (2016)	*India*	*Mc-Si*	*80*	*4.45*	*15.53*	*-*	*83.2*
Shukla et al. (2016)	*India*	*c-si/a-si*	*110*	*2.67-3.36*	*-*	*93.5-97.5*	*71.6-79.5*
Sundaram and Babu (2015)	*India*	*-*	*5MWp*	*4.81*	*6.08*	*88.2*	*-*
Kumar and Sudhakar (2015)	*India*	*P-Si*	*10MWp*	*1.96-5.07*	*13.3*	*97.0*	*86.12*
Present study	***India***	***P-Si***	***33***	***4.8-5.2***	***15.38***	***98.2***	***74.3***

V. RESULT AND DISCUSSION

The losses in the PV system corresponding to collection loss and the inverter loss are represented in the bar chart as shown in Fig. 7. below for the corresponding month. The performance ratio is defined as the ratio of final yield of the system after losses to the reference yield produced from the modules, which is given by the bar chart as shown in Fig.8. Given below with respect to the corresponding month.

As seen from the Fig.7, the nominal power of the system is 36kwp.The average collection loss of the system which occurs at the PV panel is found to be 1.21kwh/kwp/day, the loss from the inverter is found to be 0.08kwh/kwp/day. The total output generated from the system during the period of observation was found to be 46,766 KWh. The total useful energy that comes out of the inverter after the loss from the inverter, PV array is found to be 3.72 kwh/kw/day.

Fig.8. represents the performance ratio of the 33 KWp on Grid system during the period of observation. The performance ratio of the present PV system is found to be high in winter season and the average production is less in the rainy season due to the cloudy days.

The important observation that has been found by analyzing the PV Module data from installed date to till date was its degradation rate. In this case the degradation rate of the PV module is found to be around 2.64% from its initial value.

The obtained results are compared with the traditional results that were conducted in different places in the country and a comparison table is obtained by summing up the results as shown in Table-II. From the comparison table, the efficiency of inverter is the highest in the present study with minimal losses. The PV module efficiency is on par when comparing with the traditional systems.

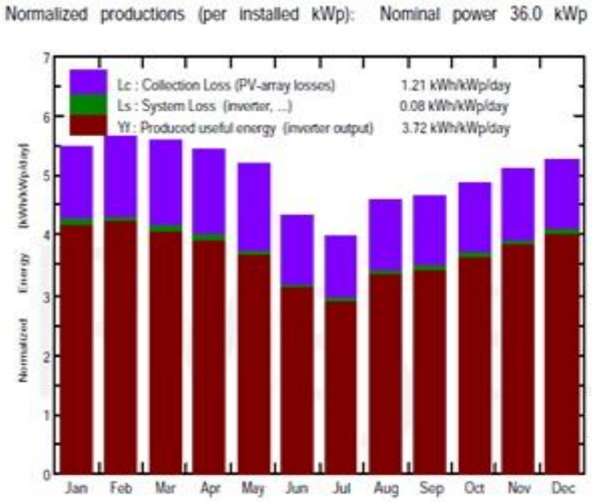

Fig. 7. Normalized production with losses

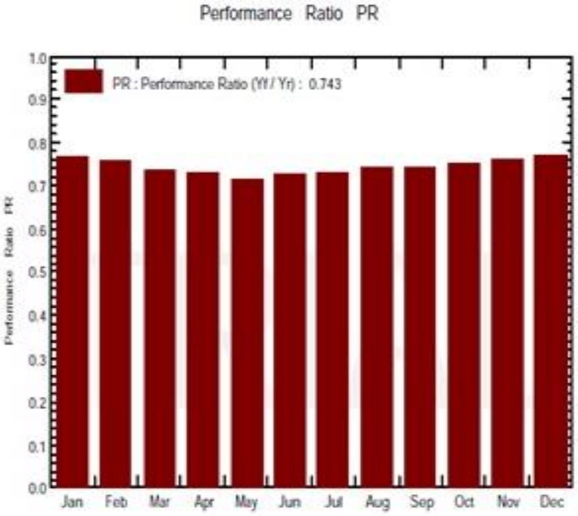

Fig. 8. Performance Ratio of the PV System

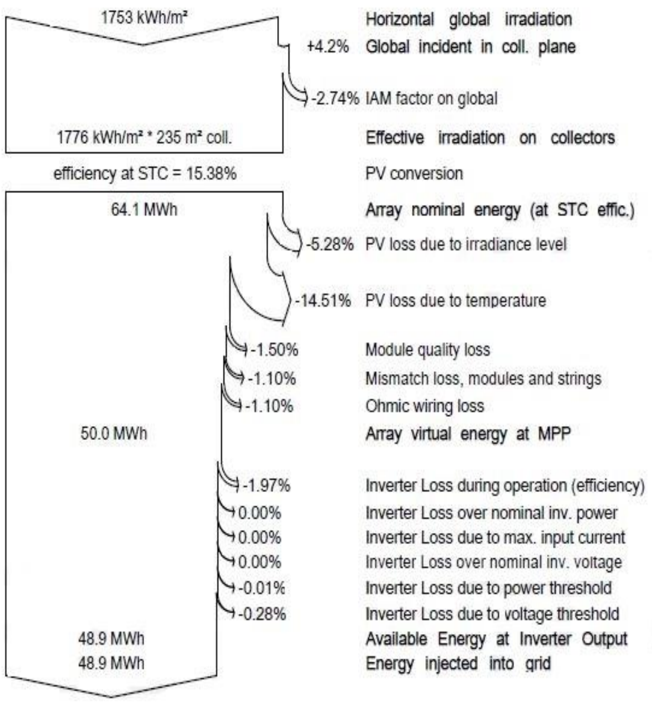

Fig. 9. System Loss Diagram

VI. CONCLUSION

The 33KWp grid connected solar system is evaluated for its performance in the third year of production by using pvsyst software. The key outcomes of this work are discussed here, the total energy injected in to the grid is 48.9MWh while the nominal energy without losses is 64.1MWh.the losses occurred due to the effect of temperature on the present system are about 14.51% and the PV loss due to the irradiance level are about 5.2% while all the other losses are accounted to be 6-7%. The module efficiency at STC is found to be 15.38%, the losses in the inverter are about 1.98% which indicates that the inverter is working satisfactorily during this period. The performance ratio of PV system is found to be 0.743.Which gives us an impression that the system is working good.

Although the system is doing good there are some recommendations made in this context to increase the efficiency of the PV System. The module efficiency of the present work is found to be 15.38%, which is high when compared to plants in other parts of India as shown in Table-II, so there is more scope for expansion of the potential of solar systems in this area. The performance ratio of the present system is found to be 0.743, which is high when compared to some of the PV systems installed in other parts of India[1].The choice of panels plays a major role in increasing the production of PV system, New technological innovations like HIT panels which uses Passivated Emitter and Rear Contact or cell(PERC) technology, which are having higher efficiencies are to be considered and they are to be preferred, as they utilize heat deposited at the back of the panel to reflect back to the panel and thereby increasing the efficiency of the panel. The use of tracking mechanism instead of using fixed base for the modules which will allow maximum utilization of the solar irradiance available for the module and thereby reduces the loss occurred due to irradiance levels.

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