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Design & Implementation of 17.25 kVA Solar Power Plant

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Abstract– *Extinction of non-renewable resources leads to more usage of renewable resources for generating electricity. Also, these non-renewable resources are not sufficient with respect to increasing demand of electrical energy of world. To solve that problem redesign for the solar system more effectively. In this paper we tried to increase module intensity for the better and sufficient output for different grids. By proper selection of module and inverter gives require output power as for commercial and industrial.*

Keyword: *Non-renewable resources, Generating electricity, Solar System.*

I. INTRODUCTION

Solar system is associated with the renewable source of energy use for the generating power through the sun radiations. Solar energy is used and developed more due to extinction of non renewable resources i.e. thermal, hydro-electrical, etc. Earlier, sunlight as a source of energy was discovered in 1704 and develops the use of this energy in regular usage, than during the invention of selenium by Willoughby Smith discovered that electricity travel through the material when it was in light. Hence, in 1870's, two American scientists, William Adams and Richard Day, become interested in the energy source and soon discovered that sun's energy develops the flow of electricity in selenium. Commercial concentrated solar power plant was first developed in 1980's. The 392 MW Ivanpah is the largest concentrate power plant in the world, located in Mojave Desert in California.
Requirement of alternative source for any plant like thermal, hydro and nuclear will be very high from economical view. Also, that kind of plants disturb environment. For that purpose generation of electricity from solar power plant is better from economical as well as environmental way. Solar system will give desired output as per requirement and mostly used as a backup source in industries. To avoid the damage from hot spot situation a new concept is to limit the current instead of limiting the voltage across the shaded shell and it is easily done by current controller [1].The efficiency of solar modules can be increased by changing intensity of solar cell or by changing the tilt angle. The optimum tilt angle is different for every months of the year and also we can collect more solar energy by choosing optimum tilt angle for each month and also from that shadow effect can be minimize which increase power generation. For increasing the reliability of solar system the conventional CSI issued which is transformer less. [2][3]
In this paper, Implementation of solar system is mainly based on the given software-Google Earth, Google Sketch up, AutoCAD, PVsyst. Google earth gives exact location of any project and gives the value of longitude, latitude and altitude. In Google sketch up 2D and 3D model can be generated and shadows effect can be analyses of any project. PVsyst gives final analysis report of any project which also includes losses. Module arrangement is adjusted in AutoCAD and it will give complete layout of any project with all the specifications.

II. SOLAR POWER PLANT

Solar radiations are captured in module which is generalized in the inverter to develop the alternating current. Such a phenomenon constructed to generate the electrical energy is said to be solar power plant. Following is the typical block diagram for generating power through solar energy.

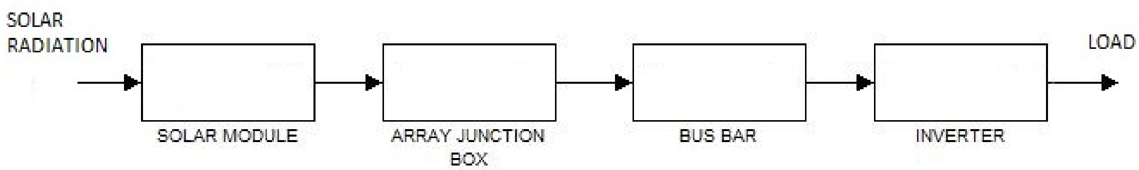

Figure 1. Solar energy generation block diagram

Figure 1 shows the basic block diagram of solar system. As shown in Figure solar radiations are capture and absorb in the solar modules. Solar modules are combining together to form a string. Array junction box combines all the strings and supplies the power to bus bar. Then it will give as input to inverter which converts dc power into ac power and this power is delivered to the load. Each block of the Figure 1 is explained below:
Solar Module: Solar module is the object in which sunlight radiations are captured. The photovoltaic cell is the basic device to store the solar energy and carry forward to the production purpose. Multi-crystalline module is used in this

power plant. Module captures the solar radiations to generate energy in output. It contains silica gel which is the material to form a cell. Generally modules are used are 60 cells, 72cells in plants. Also, the module arrangement is made properly by setting the distance between modules and collector bandwidth. The orientation of all the modules set according to where sun radiation is cover the whole module area.

Array Junction Box: As modules collect the radiation in cells, this box combines all the energy towards bus bar which is catalyst for the inverter to develop the alternating current. Array junction is practically known as string combiner box or D.C combiner which combines the divided cell strings in the solar module. Array junction box provides the interconnection between the input leads from the solar PV modules and the output lead to the recombine box or inverter. The box is customized for different configurations based on the number of strings of solar PV modules used in PV system. The combiner box enclosures are typically made out of thermo set or thermoplastic materials. Enclosures come in different sizes, depending on the number of input strings and protection features implemented in the combiner box. D.C fuses rated 2-25A in the array junction box are used by the leading manufacturers to provide protection against the over current.

Bus- Bar: A bus bar is a strip of metal used to conduct electricity within an electrical substation, distribution board, electric switchboard or other electrical equipment. A bus bar is usually a flat or hollow piece of copper, brass or aluminum. It allows heat to be released quickly because of its relatively large surface area. The cables in bus bar are made of copper having cross section area 4 mm and also in aluminum material. An electrical conductor is maintained at a specific voltage and capable for carrying a high current it usually used to make a common connection between several circuits in a system. A group of such electrical conductors at a low voltage is used for carrying data in binary form between the various parts of a computer or its peripherals.

Inverter: This is the basic device to converter direct current into alternating current through semiconductors switching combination. Through bus-bar direct current is obtained, than by inverter alternating current is developed for industrial, commercial or domestic usage through a renewable source of energy. Inverter convert variable DC input collected from PV cell into AC which is feed into electrical grid network .It is not a new process, but it has not received the attention that it deserves. Perhaps this is because it is such a low-tech and flexible solution to water problems. Solar power generated by sun in atmosphere is 1017 watts and the total demand is 1013 watts. Therefore, the sun gives us 1000 times more power than we need. If we can use 5% of this energy, it will be 50 times what the world will require. Estimation for the solar light radiation in the system has no cost as it is naturally available and also a wide range of solar energy is available in the atmosphere.

III. STATEMENT OF DESIGN

In designing of PV system the modules are main part of whole system .So, the proper arrangement of modules builds system more reliable and better. In industries for the installation purpose they initially analysis the land or site where the system is to be mounted it can be on ground or on rooftop. The exact location of any site or other different parameters like area, longitude, latitude, altitude etc come out by using Google Earth software. For the system calculation load calculation and other parameters are needed. Below problem explains each and every term related to design and implementation calculation of any plant.

Problem: To design a 17.25 kVA solar power plant. Following is the data used for developing the solar power plant; it gives different parameters and their ratings which are needed for the load as well as system calculation.

Sr. No.	Parameters	Rating
1	Overall plant capacity	17.25 kVA
2	Inverter Rating	15 kW
3	Module (P_{max})	250 W
4	V_{mp} & I_{mp}	627 V & 25 A
5	Module Area	113 m²
6	Maximum Power Voltage (V_{mp})	30.1 V
7	Maximum Power Current (I_{mp})	8.3 V
8	Open-Circuit Voltage(V_{oc})	37.2 V
9	Short-Circuit Current(I_{sc})	8.87 A
10	Irradiance	1 kW/m^2
11	No. of Module & No. of String	69 Nos. & 3 Nos. (In parallel)
12	No. of module in Single String	23 Nos. (In series)

Table 1. Data for the Calculation of Solar Power Plant

Design Process of 17.25 kVA Solar Power Plant:

Load is the very important data to design a solar system. For load calculation two different methods are available which are mentioned below, Load calculation of any solar plant is done by two methods:

i. First method is to take last three electricity bills of the plant whose load calculation is needed. Then take average of those three bills. The load selected on which the plant is mounted should be less than the average of those bills. The load selected should be equal or lower than the average electricity bill, higher value can't be selected.

ii. Second method is to calculate the load of the plant i.e. how many appliances is working and for how many time they work. Total energy consumption by appliance is counted. It can be count by multiplying power consumption of appliance and time they work for. Watt rating of any alliance is written on its data sheet. So, by checking the exact value calculation can be done.

So, by going to any of the two methods load can be count. But cost also play an important part for deciding system rating. By going to method no.2 load required for this system is 17.25 kVA. Now all the data is obtained, from this data overall system parameters can be found. Any solar system can design by following these steps,
Step 1: First select the module rating.
Module rating is selected on the base of area of site, power requirement of any plant and cost. Here, taking 250P 60 cell modules, STC value of this cell is

$$V_{OC} = 37.2\ V$$
$$V_{MP} = 30.1V$$

Step 2: Selecting total number of modules.

$$\text{Number of modules} = \frac{\text{Total plant capacity}}{\text{particuler module capacity}} \quad (1)$$
$$\text{In this plant total no of modules} = \frac{17250}{250} = 69 \text{ modules} \quad (2)$$

Step 3: Now select the inverter rating and number of inverter

$$V_{dc\ in} \text{ for inverter} = \text{total no of module} \times \text{maximum power voltage of each module} = 69 \times 30.1 = 2076.9 \quad (3)$$

According to the costing and power, inverter is selected of 15 kW.

Step 4: Deciding the number of strings.
As per available area total 69 numbers of modules is divided in to 3 strings.

$$\text{Per module string} = \frac{\text{total number of modules}}{\text{total number of strings}} = \frac{69}{3} = 23 \quad (4)$$

Step 5: Calculating the total output power
Per String Power = Maximum Power of each module × per string module = 250 × 23 = 5750 W (5)
Total Output Power = per string power × Total no of strings = 5750 × 3 = 17250 W (6)
Generated power = 17250 = 17.25 kVA

So, by choosing the correct parameter desire output voltage can be get.

IV. SOFTWARE ENVIRONMENT FOR DESIGN

For designing of any solar system software's plays an important role after the calculation of parameters. In this chapter three software's are used which are - Google Sketch Up, AutoCAD, PVsyst.
Google Sketch Up: Firstly in software environment Google sketch up is basically used to create 3D modeling and to analyze shadows impact for selected site or land to installing PV system. For designing this model the data are catching from Google earth which is longitude, altitude and latitude. This software gives the idea of day to day sun position from which the shadow impacts can be known and module position is set accordingly to sun's position. The below Figure 2 shows the 3D model of selected solar site, which is designed from the Google earth data. This software also gives the shadows effect of any particular site for different months so prediction of energy generation can be done. For viewing the shadow effect of different months there is a window available on the right side for any location in worldwide. According to that prediction modules are arranged to capture the maximum sun radiations.

AutoCAD: AutoCAD is a commercial software application for 2D and 3D computer aided design and drafting. In every project, imaginary graphics are require which is done by AutoCAD software it also includes area, modules and specification details of that particular project as shown in below Figure 3.

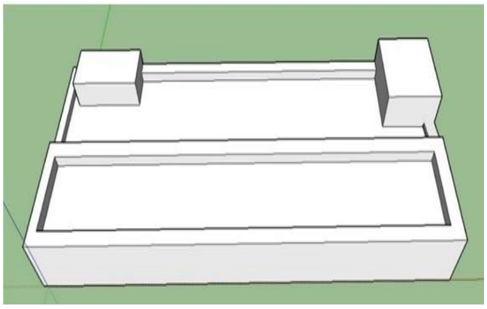

Figure 2. Model of Google Sketch up

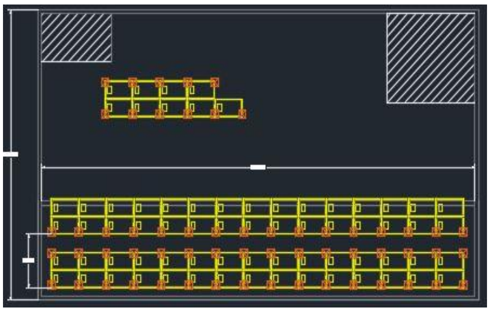

Figure 3. AutoCAD Model

AutoCAD describe our site map, position of modules, total number of modules and strings. Above Figure shows one example of AutoCAD for 17.25 kVA genration. In that model we use 69 moddules which are divided into 3 strings. For drawing of 2D or 3D model different symboles are use like corner of rectengular screen, hatch symbol , dimention symbol etc. From that we can arrange the modules for minimum shadows impact to achieve maximum efficincy on that site.The parameters and loctions which are achieved from Googlesketchup are used to create model in AutoCAD.

PVsyst: The main purpose to use PVsyst software is for result analysis which represent on graphical Figure and it also include losses.

Figure 5. Start Up Page of PVsyst

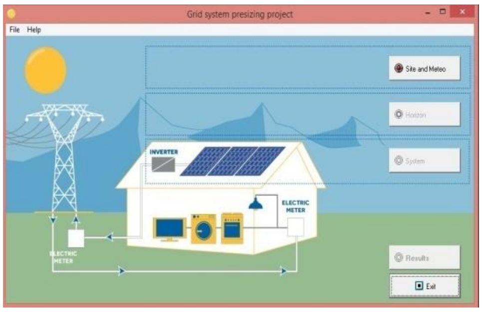

Figure 6. Preliminary design of Grid Connected System

Figure 5 shows the starting page of PVsyst in which different sections are available for different systems. Here four different sections are available to design a solar power plant- preliminary design, project design, databases and Tools and most commonly used section is preliminary and project design. In which choosing a first option Preliminary design a window will open which include the option like grid connected, stand alone and pumping. Figure 6 shows window of grid connected system option in which by choosing the site and meter option parameters of any system can change to find the load calculation, power generation etc. As well as standalone and pumping system can also be design on primary level by choosing the options of them on the startup page.

Figure 7. Project design of Grid Connected System

Now by selecting the option of project design any solar system can design and analysis, loss calculation of the whole system can be done. First select the project design option to start any kind of new solar project and then choose from grid connected, stand alone or pumping system to designing of that system. Hence, for grid connected system parameters select that option for analyze the whole system. A new window has been open for project designation as shown in Figure 7. Also it has all the steps for adding different values of project. At first, for a new project select new variant option and load the new project. There are many options are available for different parameters like orientation, system, horizon and near shadings etc. In orientation block select the proper field type and the values of plane tilt as well as azimuth according to the project. For a better production modules are placed on the north side. In system block put the rating and manufactures name of module and inverter. Then in the end mention the below remaining options for modules, string and temperature related parameters. Now selecting the horizon block any value of horizon can select for different plant. The last window generates with complete details and after that it gives main graphical result for any project.

V. IMPLEMENTATION

After studying and designing 17.25 kVA solar power plant implementation of the system is done by the analyzing result and loss calculation on software after that system connection are performed. Same as studies are done to design a high voltage power plant. Figure 8 shows the design of high rating solar system. It's a high rating solar plant which means it needs large amount of equipment as well as it is costly. It also required large amount of area for implementation of plant.

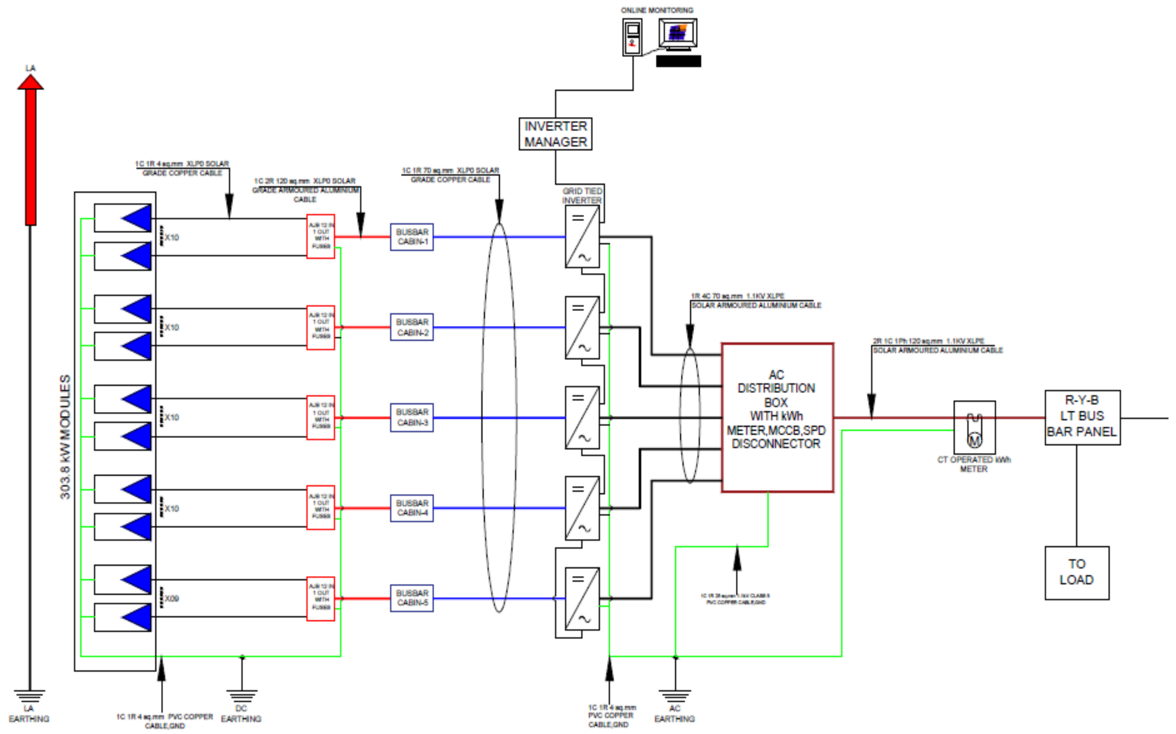

Figure 8. SLD of Solar Power Plant

Different equipments required for plant are listed below:
Solar Panels: Solar panels are used to convert the solar radiation into usable electricity by applying photo voltaic effect.
Array Junction Box: Array junction box is used in system for combining the solar strings and give single input to the inverter or bus bar.
Bus-Bar Cabin: It generally used to connect the different component when a large distance is present between the components.
Inverter: Inverter is used to convert the dc current in to ac current.
ACDB Box: ACDB box is nothing but a ac combiner box, which typically used in the larger commercial and utility scale PV power plants.
AC & DC Earthing: In solar system some component require dc earthing while some need ac earthing so both the earthing are connected in system.
CT Operated Meters: CT operated meter is used to protect the equipments of the system.
Online Monitoring System: Online monitoring system monitors all the system parameters and check if any fault occurs.
Inverter Manager: Inverter manager manage the value of inverter automatically and check if inverter is at its predefine value or not.
Lightning Arrestor: Lighting arrestor protects the whole system when earth fault or lightning stroke appear.

As shown in Figure all the solar modules are connected in parallel and form a string, each strings are connected in series. Array junction box combines all the string and pass the supply to bus bar cabin. Here, in this plant total 69 modules are used of 17.25 V. Each string contains 3 numbers of modules and total strings are 23 which are combining in different array junction box. Each array junction box combines the string and supply power in single line which passes from bus bar cabin to inverter and works as input to the inverter. Inverter is control through inverter manager and plant is continuously monitoring through online monitoring system. Each inverter output is given as input to the ACDB box. Generated power is then travel from the CT operated meter which sense if any disturbance or fault occur, then it is deliver to the bus bar panel then to load.

VI. RESULT

The input and output along with results of 17.25 kVA solar plant are generated by PVsyst software, specially developed for solar generating plant. The first result window in PVsyst shows the grid connected simulation parameters of system. In which the project name with their location as well as situations is mentioned. Also, other simulation parameters like the collector plane orientation with sheds, band and angles are shown. As well as it includes the module details, PV array characteristics, inverter specifications and loss factors of PV array and whole system.

Sr. No.	Simulation Parameters	Ratings
1	**Collector Plane Orientation**	
	Tilt angle	15˙
	Azimuth	-40
	Pitch	3 m
	Collector bandwidth	2 m
2	**PV module**	
	Total no of modules	69
	Unit nominal power of module	250 W
	Module area	113 m^2
	Cell area	101 m^2
3	**Inverter**	
	Model	TLX-15K
	Operating voltage	250-800 V
	Total no of inverters	3
	MPPT input	33%
	Unit nominal power of inverter	15.0 kW

Table 2. Simulation Parameters

Table 2 shows the simulation parameters of the plant and also it contains all the main details of plant. This all data is put into the input of PVsyst to analyze solar system to check if output obtain is accurate or not and to check the losses of the system. Simulation parameters are obtained on the first result page of PVsyst. Tilt angle for each module is 15 degree. Tilt angle are set to obtain max radiation of sun. As shown in table total modules are 69 which is connected in bunch of 13 modules to form a single string. Total 3 strings are form as there are 69 modules in system and their rating is 250 W. Single inverter is used in this system and its operating voltage is 250-800 V with 3 mppt inputs in which strings are connected.

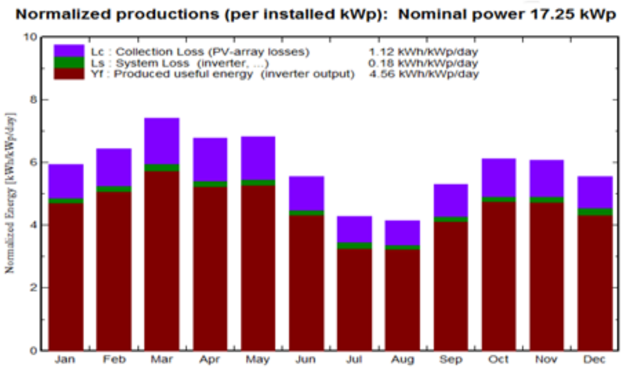

Figure 9. Graph of Normalized production per month

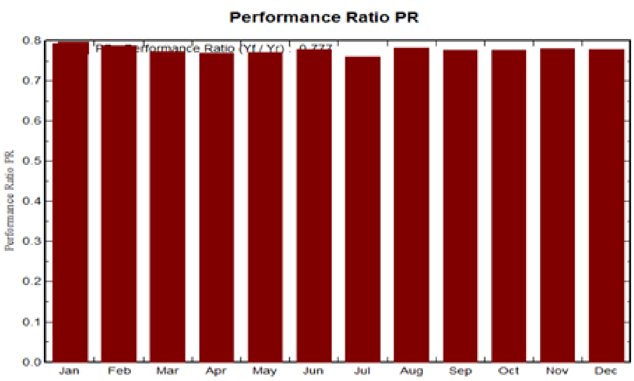

Figure 10. Graph of performance ratio in every mont

Figure 9 shows the main results in the form of production graph. Generally, system parameters are shown on start up page. Then the values of production and performance are given. First graph shows value of normalized productions per year. It shows produced energy per every month. In which array losses, system loss as well as useful energy is mentioned with different colors. As shown in graph Jan-May period has better generation of energy compared to other months, while Jun-Sept period is generating lowest energy, On the other hand Oct-Dec period also generate a good amount of energy. From this graph overall energy of the system can be predict.
Figure 10 shows the graph of performance ratio which plays an important role in the system analysis. From the performance ratio overall system performance can be found in different months. Graph shows the percentage performance ratio of every month. In which Jan and Feb has the highest performance ratio, while July has the lowest performance ratio and other months have comparatively equal performance ratio.

	GlobHor kWh/m²	T Amb ˚C	Globlnc kWh/m²	GlobEff kWh/m²	Earray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	158.5	22.09	183.8	172.7	2.607	2.515	12.51	12.07
February	162.6	23.78	180.4	170.8	2.543	2.451	12.43	11.98
March	216.3	27.5	229.9	218.1	3.183	3.064	12.21	11.76
April	202.4	29.54	203.5	191.8	2.805	2.705	12.15	11.72
May	219.3	30.5	211.9	199.5	2.927	2.823	12.18	11.75
June	174.2	29.44	166.8	155.7	2.318	2.239	12.26	11.84
July	137.6	28.37	133.1	123.3	1.854	1.744	12.28	11.56
August	130.1	27.63	128.9	119.6	1.799	1.737	12.31	11.89
September	155.5	27.97	158.8	148.5	2.216	2.129	12.31	11.82
October	174.8	28.01	189.9	178.3	2.634	2.543	12.23	11.81
November	156.9	25.35	182.4	171.1	2.547	2.457	12.31	11.88
December	148.5	23.11	172.3	162.1	2.439	2.313	12.48	11.83
Year	**2034.6**	**26.95**	**2141.8**	**2011.2**	**29.872**	**28.72**	**12.3**	**11.83**

Table 3.Period Vice Analysis.

Table 3 shows month vise analysis of system. It includes the values of global horizontal irradiation and ambient temperature for every month as well as global incident in collector plane. Effective energy at the output of the array and energy injected to grid is also mention in table. Also, the effective energy is mentioned for rough areas.

Sr. No.	Loss Factors	Losses value in %
1	Array soiling loss	2.0
2	PV loss due to irradiance	1.2
3	LID-Light Induced Degradation	1.0
4	Module Quality Loss	1.5
5	Module Mismatch loss	1.0
6	Wiring Ohmic loss	2.0
7	Unavailability of system	0.5
8	Irradiance loss	2.0
9	Inverter loss during operation	2.4
10	AC ohmic loss	1.1

Table 4. Losses of System

Table 4 shows different losses occur in the system due to various parameters. In the table array soiling loss is present which depend on the location of the plant i.e. site is dusty or clean etc. PV loss is occurred due to effect of the irradiance on the module and temperature. Module quality loss and module mismatch loss are depends on the quality of module and wrong connections. While wiring loss is happen due to wrong connection and sometime due to temperature effect. Sometime, due to maintenance purpose system will be unavailable for a particular period which increases losses and some losses are occurred during the inverter operation.

VII. CONCLUSION

As per the performed problem generation of 17.25 kVA rating through module designing, selection of inverters as per requirement, adjusting the tilt angle of module in equal duration of time of whole year, maintenance parameters, and voltage regulation of the power is concluded and calculated through PVsyst software and obtaining results simultaneously observing the losses and revalidating them. After the designing of 17.25 kVA plant studies are done to design 300 kVA power plants. Generation of plant can be increase by choosing different tilt angle in all months.

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