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Analysis of 1 MW Solar Power Plant and Implementation of Single-Axis Solar Tracker

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***Abstract*— The Sun provides the energy to sustain life in our solar system. In one hour, the earth receives enough energy from the Sun to meet its energy need for nearly a year. Photovoltaic is the direct conversion of sunlight to electricity. It is an attractive alternative to conventional sources of electricity for many reasons: it is safe, silent, and non-polluting, renewable, highly modular in that their capacity can be increased incrementally to match with gradual load growth, and reliable with minimal failure rates and projected service lifetimes of 20 to 30 years. A 1 MW power plant was surveyed, having 2 no's of 2 x 0.270/11 kV distribution transformer of 1500 kVA rating which steps up the output from the solar generation to the 11 kv switchgear. This paper simulates the feasibility of the solar plant, the system performance and losses associated with the generating plant in PVSyst software. For optimal solar production, a low cost single axis solar tracker was designed using Arduino Uno microcontroller.**

Keywords—Grid-connected system, Photovoltaic (PV), Meteo data, PVSyst Software, Arduino

I. INTRODUCTION

Electricity production using renewable energy resources (RES) reduces environmental impacts and produces least amount of secondary wastes. Natural resources like solar energy, wind power, hydropower, biomass energy and geothermal energy are the major RES for clean and green energy production.[1]. 'Solarism' is a solar power generating company located at Sudi & Tanchha village, Amod, Bharuch, Gujarat, focused on providing solar power, both as an Independent Power Producer (IPP) and as service provider to Captive Power Producer (CPP) customers. They build, own, operate and maintain grid connected solar power projects as IPP and generate revenue by entering into Power Purchase Agreements (PPA) with third parties for selling power units generated through the solar projects[6].

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[3,5].

Tracker systems follow the Sun throughout the day to maximize energy output. Solar trackers could be single axis or dual axis. The Solar Tracker generates up to 25% more energy than fixed mounting systems and provides a bankable energy production profile preferred by utilities.[4]

II. 1 MW SOLAR PLANT

A. *System Analysis*

Panel details:

- Power = 250 W, Voltage at maximum power = 30v, current at maximum power = 8.35A.
- Module efficiency = Pmax/(Area x Irr) x100 = 250/(1.6236 x 1000) x100 = 15.4%

String:

- 24 no's of panels are connected in series to make a string.
- Power = 6 kW per string, voltage = 720 V_{dc} per string, current = 8.35 A_{dc} per string.

Array Junction Box:

- 24 no's of strings are connected in parallel in AJB.
- Power = 144 kW, Voltage = 720 V_{dc}, Current = 200.4 A_{dc}.
- Total no of panels per junction box = 576 .

Inverter:

- 6 no's of AJB's are connected in parallel for the inverter input. Out of the 6, 5 no's of AJB have 24 no's of strings and the remaining 1 has 5 no's of strings. Total of 125 strings are connected in parallel for 1 inverter input.
- Power = 750 kW / inverter, voltage = 750 V dc / inverter, current = 1043.75 A dc.
- For 1 kW system, 4 no's of panels are required.(i.e. 1000 / 250Wp). Hence, for 1MW system, 4000 panels are required.

Inverter AC Output:

- Nominal power (active power) = 690 kW, nominal voltage = 270 Vac, 3-phase, frequency = 50hz. Distortion factor < 3%. 270V is step up to 11 kV by the 1.5MVA transformer and further to 66 kV by 10 MVA transformer.

B. Simulation of 1 MW Solar Plant of Solarism in PVSyst

From the calculated data, system of 1000 kWp is simulated and the performance is analyzed in the PVSyst software.

Table I. System Parameters

Parameters	**Input/Values**
PV Module	Generic module, Poly 250 Wp 60 cells
Number of modules	4000
Unit power	250 Wp
Nominal power	1000 kWp@STC, 895 kWp @ operating condition
MPP voltage	546 V
Mpp current	1640 A
Inverter	Sungrow, SG750MX
Inverter unit power	750 kW ac
Number of inverters	1

Table I shows the system parameters and operating conditions for the simulated system. The array nominal power is 1000 kWp.

Table II. Balances and Main Result

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	156.6	30.60	22.09	203.7	198.8	168.3	165.7	0.813
February	165.8	33.12	23.78	199.0	194.7	159.5	157.0	0.789
March	204.2	53.51	27.50	223.5	218.1	177.2	174.2	0.780
April	213.1	64.07	29.54	213.7	208.0	169.5	166.6	0.780
May	220.9	81.38	30.50	206.5	200.1	166.8	163.7	0.793
June	167.0	98.94	29.44	153.4	147.9	128.0	125.3	0.817
July	130.6	91.41	28.37	122.2	117.6	103.5	100.9	0.826
August	124.4	87.34	27.63	120.6	116.2	102.0	99.6	0.826
September	145.3	74.65	27.97	150.9	146.2	124.8	122.3	0.810
October	177.8	52.57	28.01	206.2	200.9	165.8	163.0	0.791
November	155.4	36.31	25.35	195.9	191.4	159.2	156.5	0.799
December	145.4	33.67	23.11	191.1	186.8	158.1	155.4	0.813
Year	2006.6	737.57	26.95	2186.7	2126.9	1782.6	1750.2	0.800

Table II depicts the balances and main results of the PV system. Yearly global horizontal irradiation is 2006.6 kWh/m^2. The yearly global incident energy on the collector plane is 2161.7 MWh/m^2. Energy available at the output of the PV array is 1782.6 MWh. The energy injected into the grid is 1750.2 kWh. The average ambient temperature is 26.95ºC. Performance ratio of the system is 80%.

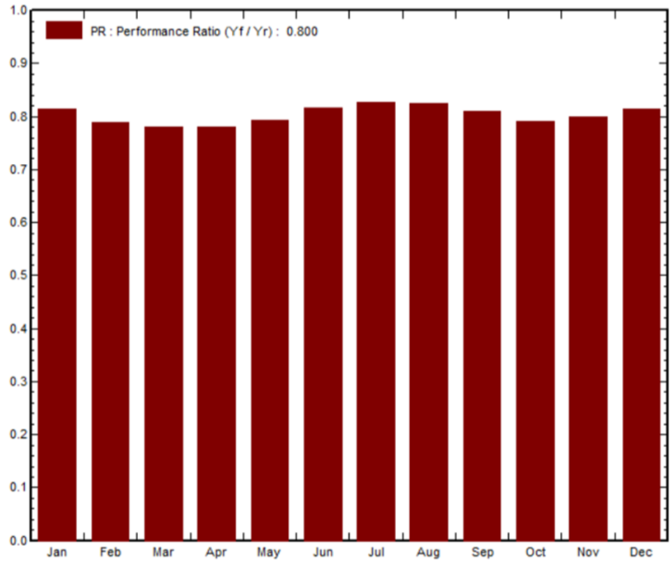

Figure 1: Performance Ratio

Fig.1 shows the performance ratio, which indicates the ratio between actual yield (output of inverter) and target yield (output of PV array), of the incident energy for the entire month of the year to be 80%. This index represent the level of utilization of the system.

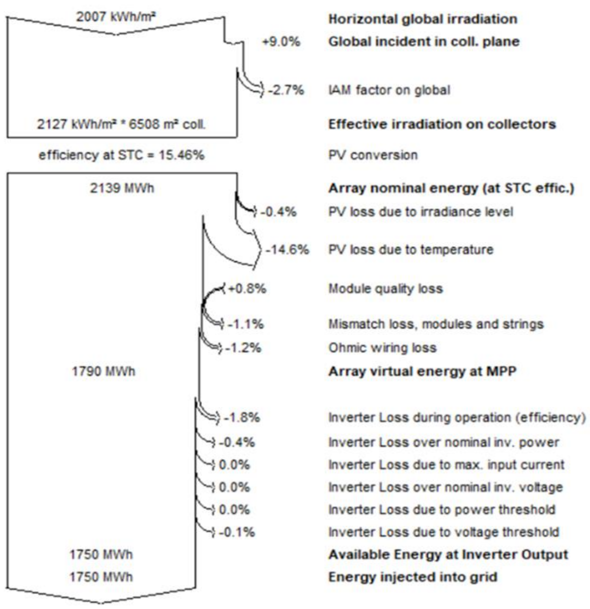

Figure 2: System Loss Diagram

The system detailed annual loss diagram is shown in Fig 2. The horizontal global irradiation is 2007 kWh/m^2, the effective irradiation on collector plane is 2127 kWh/m^2. After PV conversion, array nominal energy is 2139 MWh and efficiency at Standard Test Condition (STC) is 15.46%. Array virtual energy obtained is 1790 MWh. After the inverter loss, the available energy at output of inverter is 1750 MWh. It is

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obviously seen that the highest loss occur on the PV due to temperature which is 14.6%.

III. SOLAR TRACKER DESIGN APPROACH

The main impulsion is to design a high quality solar tracker. The principle of the solar tracking system is implemented using Light Dependent Resistor (LDR). The system consist of three main parts which are the inputs, controller and the output.

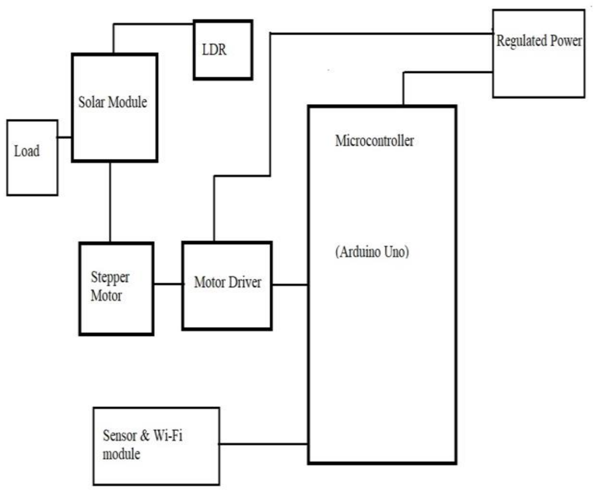

Figure.3: Block Diagram

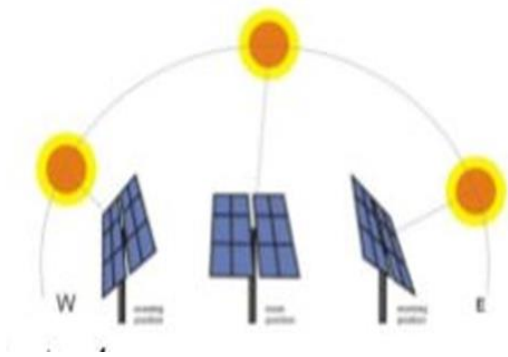

Figure 4: Illustration of Sun Path

Fig 4 illustrates the Sun path as it rises from the east and sets in the west while Fig 3 depicts the block diagram of the solar tracker to be implemented.

Two LDR's are connected to Arduino analog pin A0 & A1, which act as the input for the system. The pairs and placed at opposite ends of the solar module frame. The built-in Analog-to-Digital Converter will convert the analog value of LDRs and convert them into digital. The motor can rotate in steps, either clockwise or anticlockwise direction depending upon the sequence of the logic signals. This controlled steps corresponds to the daily Sun-hours received.

The sequence of the logic signals depends on the difference of light intensity of the sensors.(i.e. LDR1 & LDR2, where one controls the clockwise rotation and the other controls the anti-clockwise rotation of the motor). If one of the pair gets more light intensity than the other, a difference will occur on node voltages sent to the respective Arduino channel to take necessary action. The stepper motor will move the solar module frame to the position of the high intensity LDR as per programming.

For monitoring of output of the solar module, voltage and current sensors are connected to analogue pins A4 & A5 respectively. Wi-Fi module, is used for internet connection to upload the voltage and current output data in mobile application.

Figure 5: Hardware Setup

IV. CONCLUSION

The software provides a detailed analysis of all types of losses. The main uncertainties of the PV production results remain: the meteo data (source, and annual variability), the PV module model, and the validity of the manufacturer's specifications as the simulation was based on these data.

From the 1 MW grid connected system analysed, it is seen that 4000 numbers of 250Wp panels are required, 6 no's of AJB's to be connected in parallel for the inverter input, and produces annual energy of 1750 MWh, with system performance ratio of 80%.

The solar tracker design is a virtual instance of the rotation of the solar panel according to various Sun intensity received every hour of the day using stepper motor, which rotates in clockwise and anti-clockwise direction based on signal received via microcontroller and intensity of light received by the light sensing resistors. With tracking systems installed, optimal utilization of the output of solar panels can be achieved.

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