Performance Evaluation of Solar Power Plant (1.5KWh) with Auto Dual Axial Solar Tracking System

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Abstract— **In this paper we propose an off grid solar power plant (1.5 KWh) with auto dual axial solar tracking system. It is indigenously designed, developed and installed to harness the maximum possible solar radiation throughout the whole year. This system is developed to improve the generation of electrical power through solar power plant by tracking the sun continuously for the whole day, from east to west and for the whole year from north to south. This solar power plant with sensor based dual axial tracking system is designed to suit any geographical location of the place. To monitor and store the various parameters like solar panel current, battery voltage, solar radiation and wind speed, online data logging system (SCADA) and energy meter are installed with the power plant and the results are used for further analysis. Careful precautions are taken to protect the solar panels modules and tracking system from harsh conditions like cyclones. Other components of the system like batteries, inverter and electrical appliances are protected through specially designed "Auto Grid Changeover System with Timer and ELCB". Day to day observations are collected through registered server and harnessed power is calculated with the power curves to evaluate the performance of the designed system.**

Index Terms— **Dual axial, solar tracker, Sensors, Anemometer, off grid, data logging, SCADA, Auto grid-changeover**

I. INTRODUCTION

The increasing demand of energy, continuous reduction in existing conventional energy sources, the growing concern regarding environment pollution and difficulties in finding new fossil resources, have forced mankind to go for an alternative energy options for production of electrical energy using clean, non-conventional energy sources such as solar energy, wind energy, hydro energy etc. Thus, renewable energy resources are the effective and efficient solution for the environment related issues. Each of these renewable energies has their own importance depending upon their amount and duration of availability at particular regions. [1-4].

India is blessed with ample solar radiation (between 5 to7 KWh/m^2/day which is sufficient to set up 20MW solar power plant per square kilometer of land area) [5] and most of the country receives between 300 to 330 sunny days a year. Solar energy can be utilized to generate an electrical power in mainly two ways –solar thermal and solar photovoltaic; the later one is simpler way. The power from the sun intercepted by earth is 1.8×10^{11} MW, which is many times larger than the present rate of consumption of

all the energy consumption. At present the worldwide solar PV capacity is about 80,000MW [6, 7].

The efficiency of conversion in solar panels is one of the most important issues for many academic and industrial research groups all over the world. Today the conversion efficiency of solar panels does not exceeds approximately 13 % for the most advanced spherical cell designs, though it is expected to rise up to 23% by 2020. Among the proposed solutions for improving efficiency of PV conversion, some important are- solar tracking, optimization of solar cell configuration and geometry, new materials and technologies, etc. [8-12].

To harness the maximum possible solar radiation on solar panels, we have designed and developed the auto dual axial solar tracking system mounted with the solar power plant of the capacity 1.5KWh. Efficiency of the whole solar power plant is affected by the individual efficiencies of all the components used in the PV system, which is affected by many parameters like solar flux, temperature, relative humidity, charging and discharging conditions of battery bank, inverter efficiency, module degradation due to aging, etc[13-14]. We have attached various sensors and data logging system to measure, monitor and store various physical parameters for further analysis. According to the analysis based on the available database from MNRE (Ministry of New and Renewable Energy) and Lanco Infratech, one single axes tracking system equipped PV system could earn 34.3% additional revenue compared to a project using conventional PV technology over 25 years through sale of electricity[15]

This solar power plant is working successfully since June 2012 on the terrace of Department of Physics, Sardar Patel University, Vallabh Vidyanagar, Gujarat, India. As per our knowledge, this is country's first of its kind, indigenously designed, developed and commercially installed solar power plant with auto dual axial tracking system. One such power plant has been installed in the month of April- 2013, on "Gnayoday" building terrace providing electrical power to the office of the vice chancellor of sardar patel university, Vallabh Vidyanagar, Gujarat. Two power plants are installed at MBA department, Sardar Patel University, Valabh Vidyanagar. Two more power plants (On-Grid) are being installed at Agro-Economic Research Centre, Sardar Patel University, Vallabh Vidyanagar, Gujarat.

II. EXPERIMENTAL

A. *Solar Power Plant (1.5KWh)*

Solar panels are mounted on the specially designed aluminum structure having aeration spacing between each panel, with

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necessary series and parallel combinations to generate an output of 48V, 1500 watt (20 panels, each of 75 Watt for first three installations and 6 panels, each of 250Watt for last installation). This output from the solar panels is fed to the solar charge controller through proper shunt (for current measurement). The specially designed solar charge controller has a unique feature of sensing and controlling battery bank voltage level to protect from over charging conditions. DC energy meter displays the charging current, battery voltage and usage of power, through its scrolling display. Data logging system continuously monitor and store four parameters – charging current, battery bank voltage level, solar panels temperature and solar radiation. SCADA system transmits these data to the registered server for storage and further utilization.

Auto grid changeover system with timer device continuously senses the battery bank voltage level for its lower discharge level which can be set as per the requirement. Particularly in the rainy season, when solar radiation is not enough, or when the usage of power is more than the stored and generated power, the charging of battery bank will begun through conventional grid power to provide continuous output power. With the timer device the power usage time period can be set as per the requirements. Lead Acid Tall Tubular batteries (12V, 100Amp – 8 Nos.) are connected in series and parallel mode to provide 48V, 200A storage capacity (9.6 KW). Finally the battery bank output reaches to the inverter (3.5KVA) and its output is fed to the electrical appliances through ELCB.

B. Sensors Used

Various sensors and devices are used to measure temperature, solar radiation, and wind speed. Temperature of solar panels is measured with the thermocouple sensor attached at the bottom of the panel structure. Solar radiation can be measured directly or indirectly as per the requirements. Direct radiation measurement can be done using pyranometers or pyrheliometers. Sometimes lux meters can also be used (with proper conversion of lux to watt/m^2). The solar radiation data should be measured continuously and accurately, but in many areas of the world, due to financial or technical problems, it may not be available easily [16].

C. Dual Axial Solar tracking System

It is installed with the solar panels foundation and the structure. Two DC motors are attached with the necessary mechanical components and limit switches. Two pairs of light sensors (horizontal and vertical) sense the maximum solar radiation and accordingly place the solar panels in appropriate direction and angle for the whole day and throughout the year.

D. Safety Precautions

Necessary electrical power to solar tracking system, DC energy meter, SCADA system and other components of the power plant is provided through "Dusk to Dawn Sensing" device. After sunset (sufficiently low sunlight) this device will cut off the electrical power to the whole system to avoid its unnecessary consumption during night time. An anemometer is installed on the solar panels mounting structure to sense the wind speed to avoid the damage to the structure at high wind speeds (> 15m/s). If the wind speed reaches beyond the set limit, solar tracking system place the panel structure parallel to ground position for the certain period of the time (adjustable). A complete block diagram of the solar power plant with auto dual axial tracking system is shown in figure -1.

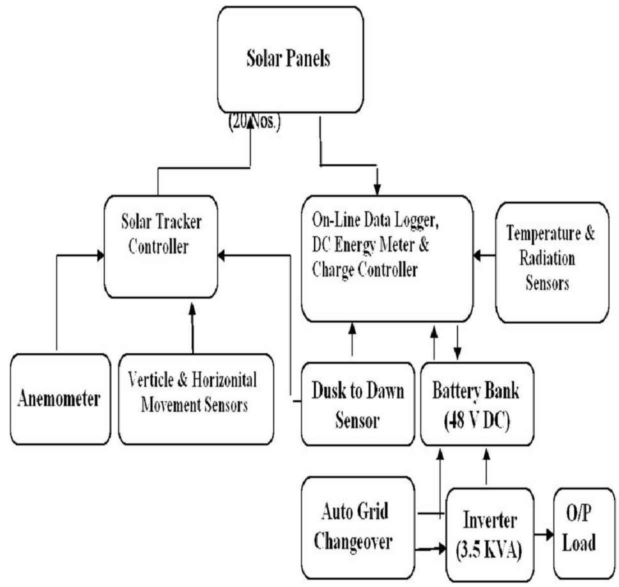

Figure -1: Block Diagram of Solar Power Plant (1.5 KWh) with Dual Axial Tracking System

III. RESULTS AND DISCUSSION

The electrical power generated from the solar power plant is provided to the various laboratories and classrooms, which is sufficient to drive approximately 20 fluorescent lights and 15 fans during an office hours (from 10.30am to 5.30 pm) through timer device. Day to day data (current, voltage, temperature and solar radiation) is collected through data logging system and through SCADA system, from server. The online data logging system measure the all four parameters every minute, from sunrise to sunset time period. For convenience in collecting the hard copies of the observations, we note the readings after every 16 minuet of time interval and finally calculate the generated power through excel software.

To evaluate the effect of dual axial tracking system on the solar power plant generation, two consecutive sunny days (cloudless) are selected as – 21st and 22nd of March -2014. On 21st of March, the solar panel structure was kept at the fixed angle (67.5°), while on the next day (22nd March, 2014) the solar panels were tracking the sun throughout the whole day.

S. No	Time	Current (A)	Voltage (V)	Power (W)
01	6:24	0.26	48.56	12.6256
02	6:40	0.16	48.25	7.72
03	6:56	0.36	48.72	17.5392
04	7:13	0.78	48.72	38.0016
05	7:29	1.3	49.19	63.947
06	7:45	2.07	49.89	103.2723
07	8:01	3.11	49.66	154.4426
08	8:18	4.14	50.6	209.484

09	8:34	4.77	50.6	241.362
10	8:50	6.32	51.22	323.7104
11	9:06	7.2	50.99	367.128
12	9:22	8.24	50.83	418.8392
13	9:38	9.27	51.14	474.0678
14	9:55	11.09	51.69	573.2421
15	10:11	12.07	51.85	625.8295
16	10:27	12.9	52.16	672.864
17	10:43	13.88	50.36	698.9968
18	11:00	14.56	49.03	713.8768
19	11:16	15.08	49.03	739.3724
20	11:32	15.75	47.94	755.055
21	11:48	15.8	48.41	764.878
22	12:04	16.22	48.41	785.2102
23	12:21	15.96	47.23	753.7908
24	12:37	16.11	48.48	781.0128
25	12:53	16.06	48.56	779.8736
26	13:09	15.7	48.25	757.525
27	13:25	15.8	48.41	764.878
28	13:42	15.34	48.33	741.3822
29	13:58	14.71	49.27	724.7617
30	14:14	13.94	50.67	706.3398
31	14:30	13.37	50.99	681.7363
32	14:47	12.49	50.67	632.8683
33	15:03	11.24	50.36	566.0464
34	15:19	10.15	50.13	508.8195
35	15:35	9.33	49.42	461.0886
36	15:52	6.99	49.19	343.8381
37	16:08	6.94	48.72	338.1168
38	16:24	5.34	48.56	259.3104
39	16:40	4.2	48.72	204.624
40	16:57	2.95	47.94	141.423
41	17:13	1.76	49.11	86.4336
42	17:29	0.73	49.11	35.8503
			TOTAL	**19031.18**

Table – 1: Observations of Solar Power Plant without Tracking System (Angle =67.5°) On 21st March-2014

S. No	Time	Current (A)	Voltage (V)	Power (W)
01	6:26	0.26	48.95	12.727
02	6:43	0.21	48.8	10.248
03	6:59	0.98	48.8	47.824
04	7:15	3.21	49.42	158.6382
05	7:31	5.8	50.52	293.016
06	7:47	8.24	51.22	422.0528
07	8:04	10.15	51.07	518.3605
08	8:20	11.92	51.61	615.1912
09	8:36	12.9	52.32	674.928
10	8:52	13.63	52.47	715.1661
11	9:08	14.3	52.39	749.177
12	9:25	15.54	52.55	816.627
13	9:41	16.01	53.33	853.8133
14	9:57	17.15	53.57	918.7255
15	10:13	17.25	53.8	928.05
16	10:29	17.2	54.35	934.82
17	10:46	17.98	50.99	916.8002
18	11:02	17.82	49.19	876.5658
19	11:18	18.08	49.03	886.4624
20	11:34	17.87	49.5	884.565
21	11:51	17.98	27.68	497.6864
22	12:07	18.6	48.33	898.938
23	12:23	18.5	48.8	902.8
24	12:39	18.24	48.64	887.1936
25	12:55	18.75	47.86	897.375
26	13:12	18.18	48.64	884.2752
27	13:28	18.6	48.8	907.68
28	13:44	17.72	48.17	853.5724
29	14:00	17.72	49.66	879.9752
30	14:16	17.36	50.21	871.6456
31	14:32	16.89	49.97	843.9933
32	14:49	16.16	50.21	811.3936
33	15:05	15.85	50.83	805.6555
34	15:21	15.13	50.52	764.3676
35	15:37	9.69	51.46	498.6474
36	15:54	13.42	51.53	691.5326
37	16:10	11.97	50.83	608.4351
38	16:26	10.88	50.13	545.4144
39	16:42	9.12	50.75	462.84
40	16:58	6.68	50.28	335.8704
41	17:15	4.04	50.67	204.7068
42	17:31	1.19	50.28	59.8332
			TOTAL	**27347.58**

Table -2: Observations of Solar Power Plant with Dual Axial Tracking System taken on 22nd March 2014

CONCLUSION

All the parameters were collected through data logging system and stored for further analysis as shown in table -1 and table -2. Figure -2 shows the power curves for both – tracking and non-tracking (fixed) modes, which indicates a considerable increase in the generated power (app. 30% to 40%) when the power plant was operated in tracking mode. the pay-back period of the solar tracing system will be of about five years.

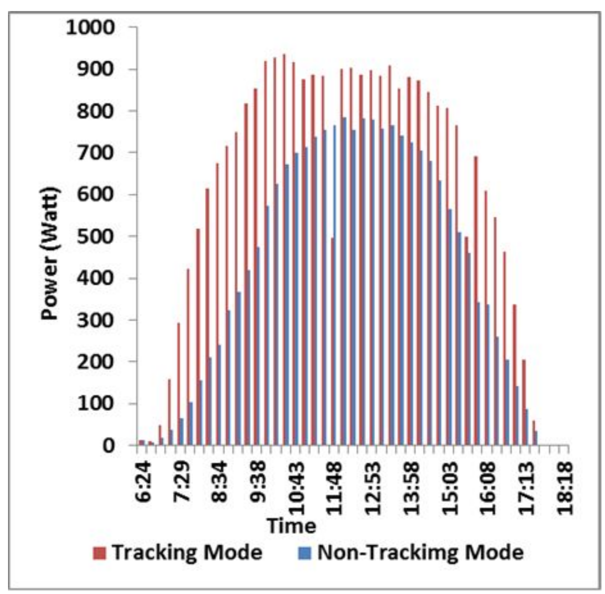

Figure -2: Power curves of solar power plant operated in tracking and non-tracking modes

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