Design, Development and Performance Evaluation of Universal Auto Dual Axial Solar Tracking System

J.R.Gandhi, S.N.Jha , Harshvardhan Jha, Shreya Gandhi

***Abstract*— In this paper we propose an indigenously designed and developed dual axial solar tracking system for off grid solar power plant of 1.5KWh (in performance from last two years) to harness the maximum possible solar radiation throughout the whole year, improving the electrical power generation. This sensors based system is designed to suit any geographical location of the place. The system monitors 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 to observe the results for further analyses. 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 fossil fuels with increases 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. Each of these has their own importance depending upon their amount and duration of availability at particular regions. [1-3]. India is blessed with ample solar radiation (between 4.5 to 6 KWh/m^2/day) and most of the country receives between 300 to 330 sunny days a year which is the favorable condition to utilize solar energy in both solar photovoltaic and solar thermal route. 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 [4-6].

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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 (to receive maximum solar radiation), optimization of solar cell configuration and geometry, new materials and technologies, etc. [7,8].

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 panels 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[9]. 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[10]. About 40% more generation can be achieved with the dual axis solar tracking system attached with the fixed solar power plant with increased cost about 30% [11-12].

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 then commercially installed solar power plant with auto dual axial tracking system in various parts of the country. 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 more power plants are installed at MBA department, Sardar Patel University, Valabh Vidyanagar. All these four power plants (1.5KWh each) are working satisfactorily.

II. EXPERIMENTAL:

Solar Power Plant (1.5KWh):

20 solar panels (12V, 75W each) are mounted on the specially designed hot dip galvanize structure having aeration spacing between each panel, with necessary series and parallel combinations to generate an output of 48V, 1500 watt. 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 is fed to the inverter (3.5KVA) and its output is delivered to the electrical appliances through ELCB.

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 luxmeters 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.

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.

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.

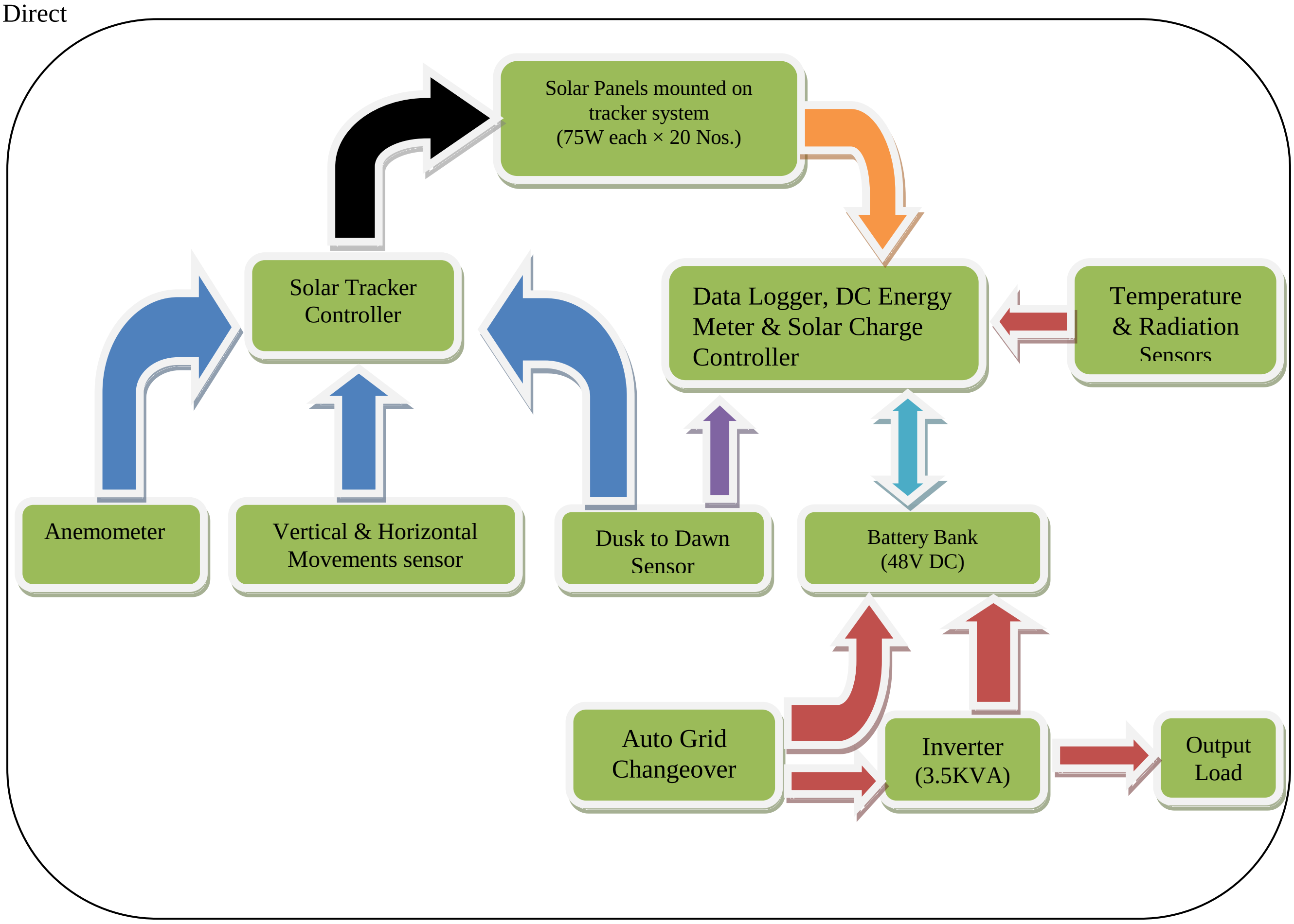

figure -1: Block Diagram of Solar Power Plant (1.5 KWh) with Dual Axial Tracking System

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 – 14th and 15th of March -2013. On 14th of March, the solar panel structure was kept at the fixed angle, while on the next day (15th March, 2013) the solar panels were tracking the sun throughout the whole day. All the parameters were collected through data logging system and observations are tabulated in table-1. Power curves for both modes are shown in figure – 2. Here we observed that due to the utilization of power during day time (parallel with charging) the storage losses are avoided so we can have approximately 10% more power compare to the power plants working during night time.

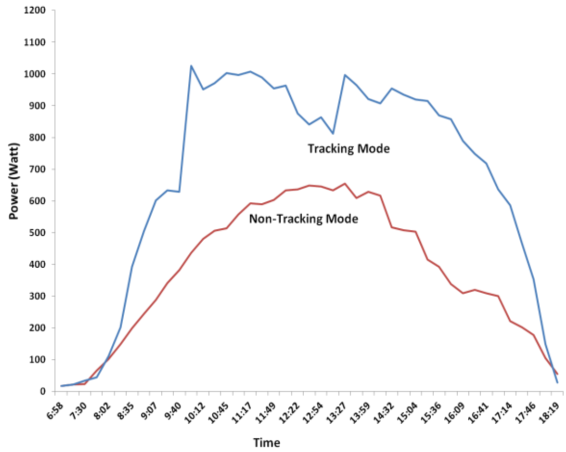

Figure -2: Power curves for tracking and non-tracking modes of solar panels

Sr. No.	Time	Power (W) (14-03-2014) Non-Tracking Mode	Power (W) (15-03-2014) Tracking Mode
01	6:58	17.3988	17.3124
02	7:14	22.8984	22.5318
03	7:30	23.2704	35.1641
04	7:46	66.2985	45.0864
05	8:02	103.1067	111.9708
06	8:19	148.798	202.5252
07	8:35	199.364	392.4076
08	8:51	244.5227	504.801
09	9:07	288.5455	601.4064
10	9:24	342.055	634.1255
11	9:40	381.7333	628.9816
12	9:56	436.2636	1024.9317
13	10:12	480.1218	951.0288
14	10:28	507.1955	970.8407
15	10:45	514.2176	1002.4179
16	11:01	557.2875	997.2948
17	11:17	592.4256	1007.9433
18	11:33	590.1138	989.5704
19	11:49	603.7486	954.6075
20	12:06	633.6043	962.922
21	12:22	636.7044	875.8505
22	12:38	648.1065	841.1844
23	12:54	646.3978	863.3625
24	13:10	633.1135	811.9696
25	13:27	654.1366	996.9015
26	13:43	609.7364	964.8912
27	13:59	628.719	920.368
28	14:15	616.2794	907.136
29	14:32	516.9384	954.7944
30	14:48	508.2547	934.1592
31	15:04	503.9441	919.0098
32	15:20	416.42	914.4095
33	15:36	392.3164	869.8415
34	15:53	339.01	856.9638
35	16:09	310.286	790.0512
36	16:25	320.9112	748.762
37	16:41	310.1004	718.1658
38	16:57	300.4053	636.7044
39	17:14	221.4585	587.1976
40	17:30	202.4472	465.4467
41	17:46	178.4628	353.694
42	18:02	105.27	148.98
43	18:19	55.98	28.1694
Total Power (watt)		**16,508.38**	**29,165.88**

Table -1: Observations for tracking and non-tracking modes
(Logger ID: SW000122, Name: Physics Department)

IV. Conclusion:

It is clear from the observation table that the solar power plant system with dual axial tracking system generates about more than 50% of the power for particular days (here 14th and 15th March, 2013) compared to the solar power plant without tracking system. We have the generation data of the whole year and there is an average 40% to 45% of increased generated power for the solar power plant with dual axis tracking system. The cost of the solar tracking system is approximately 25% of the whole solar power plant (1.5 KWh). This increased cost can be recovered within about 3 years with an increased power generation.

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