An Experimental Study of Greenhouse Gas Concentration on the Maximum Power Point of Solar PV Panels

Bhabani Patnaik
School of Electrical Engineering
KIIT Deemed to be University
Bhubaneswar, India
bhabani.twinkle@gmail.com

Sarat Chandra Swain
School of Electrical Engineering
KIIT Deemed to be University
Bhubaneswar, India
scs_132@rediffmail.com

Ullash Kumar Rout
Department of Electrical Engineering
College of Engineering and Technology,
Bhubaneswar, India
ullashrout@rediffmail.com

***Abstract*−The energy demand increases along with demographic and development growth. India is the second-most populous country in the world and most of its population needs more energy as its human and energy development indices are rather low. So, the country depends on cheaper sources of energy which have ample effects on the environment. Many energy sources are polluting, but solar energy is pollution-free and its availability is abundant with zero cost. Solar Photo Voltaic (PV) technology is the best technology to harness electricity. The effect of varying environmental factors regulates the performance factors of this technology. Its efficiency mainly depends on the concentration of greenhouse gases (GHGs), ambient temperature, module temperature, incoming solar radiation intensity, and PV material composition. To understand the behavior of solar panels on maximum power point under various GHGs concentrations, three experiments were conducted. One in normal atmospheric CO_2 concentration and two in higher CO_2 concentration chambers.**

Keywords-solar PV; GHGs; CO2 concentration; OTC; MPP

I. INTRODUCTION

As of 2019, 35% of India's installed electric generation is from renewable sources [1], which is globally the largest producer percentage. Even though India is committed by the Paris agreement that by 2030, 40% of its total electric energy will be generated from non-fossil fuels, it targets to achieve 57% by 2027. Until the end of 2019, India's total renewable energy capacity was 130.68GW which is 35.7% of its total electricity generation [2]. The government of India has focused on solar PV systems due to their reliable and cost-effective nature [3]. Especially in India, the climatic conditions are suitable for this technology because it needs higher solar irradiation as input to acquire better output at standard test conditions [4]. Nowadays, different types of solar PV modules are used (polycrystalline, monocrystalline, etc.) [5]. The output of a solar PV depends on various factors like Greenhouse Gases (GHGs), module material, panel area, cable thickness, climatic conditions (humidity, temperature), etc. [6]. Due to the growing population and the climate change, GHGs also increase vigorously. GHGs include CO_2, CH_4, NO_2, SF_6, O_3, perfluorocarbons (PFCs), water vapors, etc. Out of all these gases, CH_4 and CO_2 have the highest effect due to their higher concentrations in the atmosphere (16% and 65% respectively). It can be concluded that it is necessary to produce more green electricity as the climatic changes [7].

Corresponding author: Bhabani Patnaik

II. THE CONCENTRATION OF CO_2 IN THE ATMOSPHERE

The concentration of CO_2 in the atmosphere ranges from 380 to 420ppm, to an average of 400ppm. It has been shown that the polluting gases from fossil fuels and industry will grow by 3.2% by 2020. The burning of fossil fuels such as coal, petroleum products, and natural gas produces CO_2. It is observed that the rate of growth is increasing day by day due to the heavy demand for energy production and transportation [8]. In this paper, a higher concentration of CO_2 was taken to analyze the performance of solar PV panels under these climatic conditions because as the CO_2 concentration increases, so is the demand of renewable energy (i.e. especially solar PV technology). From Figure 1, we can see the rate of growth of CO_2 in every 10 years.

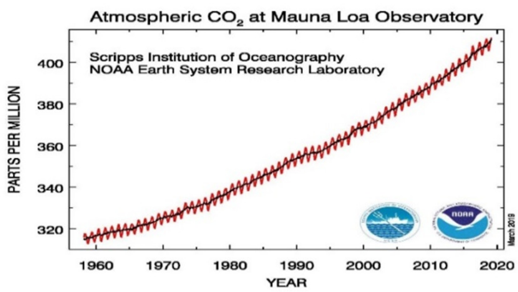

Fig. 1. The increasing rate of CO_2 concentration.

III. EXPERIMENTAL ANALYSIS

An experimental analysis has conducted in the National Rice Research Institute, Cuttack. They had built special chambers, known as Open Top Chambers (OTCs) [9], where the concentration of CO_2 is kept higher than its atmospheric concentration (400ppm).Two OTCs were made with two different concentrations of CO_2, 550ppm and 575ppm respectively. The experiment was carried out for three days (10 A.M. to 4 P.M.) in dry season (oct-15-2019 to oct-17-2019). The OTCs were used for conducting the CO_2 enrichment experiment. They were arranged in the field with a block design which is rectangular in shape (6m×4m×3m). These chambers are made up of transparent polycarbonate sheets with about 80 to 90% transparency. The upper part of the OTC is open. The temperature for all the chambers was recorded with a digital thermometer. Pure CO_2 gas was blown (2.5kg/cm^2) inside the OTCs through perforated polyvinyl tubes regulated by solenoid valves. The CO_2 data logging, sampling and the concentration of each CO_2 on each OTC were performed by a personal computer (PC) through an automatic digital meter and a microcontroller. Figures 2-3 show the design of open-top chambers and the system where the CO_2 concentration, temperature and humidity were recorded.

Fig. 2. OTCs with different CO_2 concentrations.

Fig. 3. The recording system.

In order to evaluate the performance of the solar PV panels under higher CO_2 concentrations, three 20W PV modules were kept in three different OTCs. The experimental set-up of each chamber is given in Figures 4-6. Each module was kept in its respective chamber and the measuring instruments were kept outside, so that the effect of CO_2 on the solar PV panel could be properly analyzed.

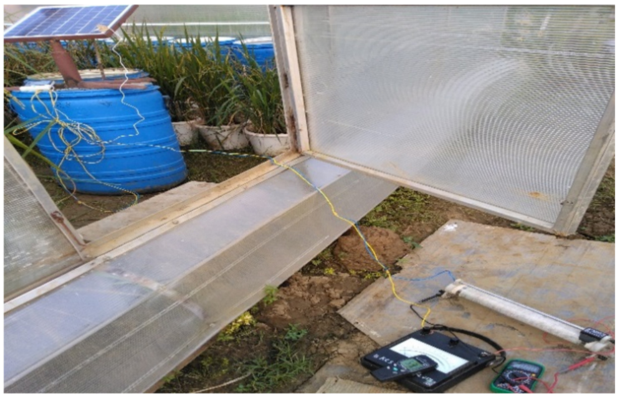

Fig. 4. Solar PV Panel under OTC 1 with 575ppm CO_2 concentration.

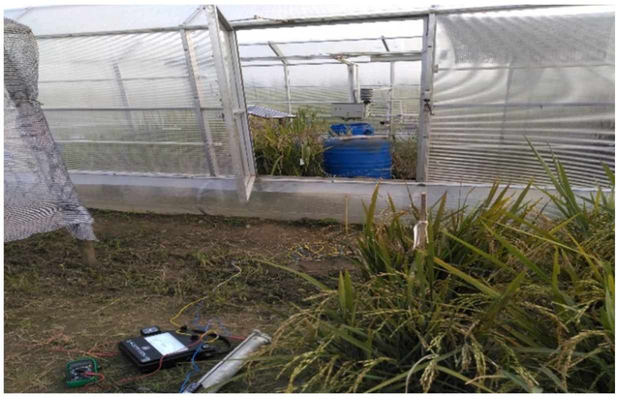

Fig. 5. Solar PV panel in OTC 4 with 550ppm CO_2 concentration.

Fig. 6. Solar PV panel on atmospheric CO_2 concentration of 400 ppm.

The solar PV module description and the required instruments for the experiment are given in tabular form in Table I. The experiment was conducted in order to acquire knowledge of the effect of higher concentrations of CO_2 on the performance of a solar PV module. The experimental analysis has continued for three days and the data were properly synthesized and analyzed. In this paper, the data of only a single data are shown, representing the best outcome from the three-day experiment.

TABLE I. REQUIRED INSTRUMENTS FOR THE EXPERIMENT

Instruments required	Range	Unit
Solar panel	20W	3
Ampmeter	0-1A (DC)	3
Voltmeter (multimeter)	0-100V (DC)	3
Rheostat	0-145Ω	3
Solar meter	Measuring irradiation	1
Solar PV stand	Tilt angle-22deg.	3
Thermometer	0- 500^{0}C.	3

TABLE II. SOLAR PV MODULE SPECIFICATIONS

Parameter	Specification
Maximum power	20W
Maximum voltage	18.25V
Maximum current	1.10A
Open circuit voltage	21.96V
Short circuit current	1.17A
Cell technology	Polycrystalline
Dimension (mm)	(356×490×20)

IV. RESULTS

All the data were taken simultaneously for the three systems on a sunny day. Voltage, current, ambient temperature, and module temperature of all setups were taken each hour from 10 AM to 4 PM. The Maximum Power Point (MPP) was traced from these data.

In Figure 7, the data were taken at 10 AM when the irradiation was 715W/m^2, in Figure 8, at 11 AM when the irradiation was 850W/m^2, in Figure 9, at noon when the irradiation was 915W/m^2, in Figure 10, the data were taken at 1 PM when the irradiation was 750W/m^2, in Figure 11, the data were taken at 2 PM when the irradiation was 660 w/m^2, in Figure 12 at 3 PM with 550 W/m^2 irradiation, and in Figure 13at 4 PM when the irradiation was 400W/m^2.

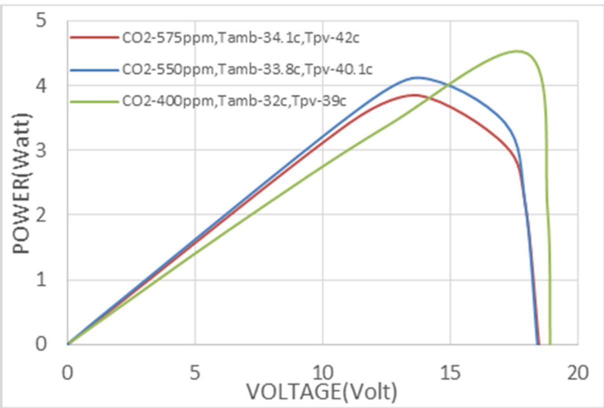

Fig. 7. PV characteristics at 10 AM.

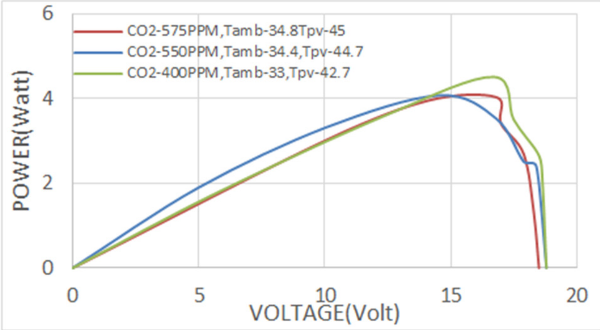

Fig. 8. Solar PV characteristics at 11 AM.

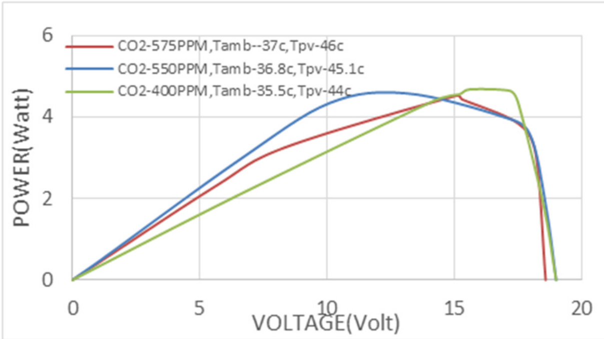

Fig. 9. Solar PV characteristics at 12 AM.

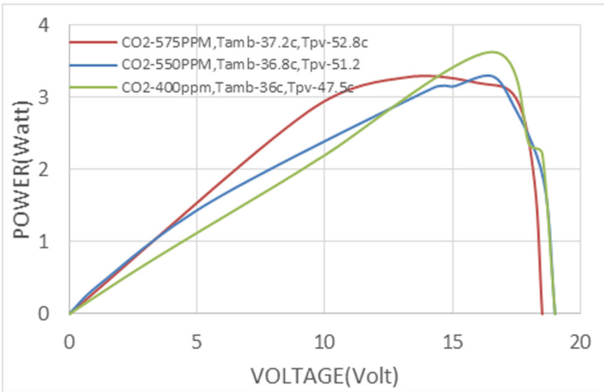

Fig. 10. Solar PV characteristics at 1 PM.

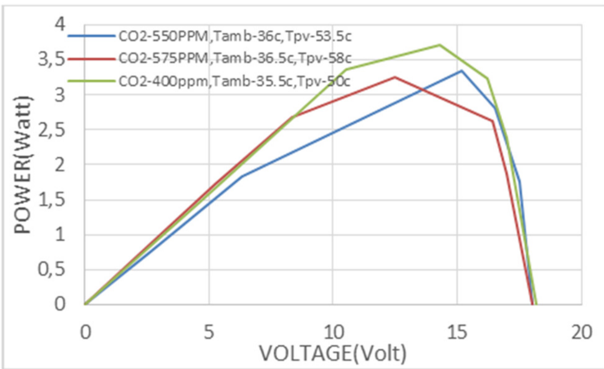

Fig. 11. Solar PV characteristics at 2 PM.

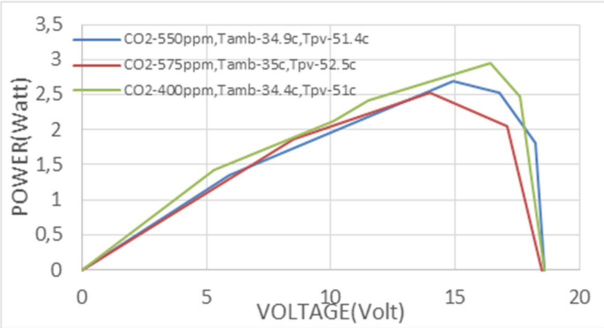

Fig. 12. Solar PV characteristics at 3 PM

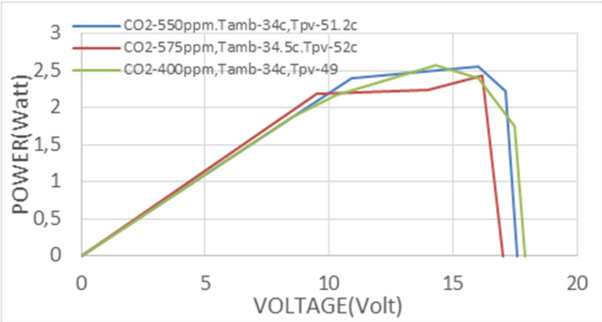

Fig. 13. Solar PV characteristics at 4 PM.

V. DISCUSSION

We can verify from the graphs that as the irradiation increases, the temperature of the panel also increases but at the same time, the increase of CO_2 concentration has a major effect on the temperature of the solar panel. At 10 AM, the maximum power of the solar panel at 575ppm CO_2 was 3.85W, at 550ppm it was 4.125W, and at 400ppm it was 4.5W. Similarly, at 11 AM the maximum power of the solar panel at 575ppm was 4.03W, at 550ppm was 4.074W whereas at 400ppm it was 4.509W. We can see that when the panels were under the highest radiation (noon time), the maximum power of solar panel at 575ppm was 4.53W, at 550ppm was 4.585W whereas at 400ppm it was 4.816W. Similarly, we can observe at every hour of that day the output maximum power or MPP of the solar PV module at 550ppm is less than the MPP of the PV module at 400ppm (ambient). And the module which is kept at 575ppm gives less MPP than the module kept at 550ppm. It should be noted that the same irradiance is absorbed by all the panels and that the data were taken simultaneously. Due to the higher CO_2 concentration, the ambient temperature of 550ppm and 575ppm OTCs was higher than the ambient temperature of the panel with 400ppm CO_2 concentration. Due to the increase in the ambient temperature of the OTCs, the solar PV module temperature increased, which effected the MPP of the panel as shown in Figures 7-13. A small increase of the ambient temperature affects disproportionately the panel temperature and thus the maximum power of the solar PV panel is gradually decreasing.

VI. CONCLUSION

In 2000, the concentration of CO_2 in the atmosphere was 366ppm, and now (2020) the concentration of CO_2 is 400 to 405ppm. Meanwhile, the demand for solar PV energy is increasing dramatically. Research in many aspects is conducted to get maximum efficiency from the solar PV panels. There are many factors present in the atmosphere by that affect the efficiency of solar PV panels. From this experimental analysis it was observed that due to the higher concentration of CO_2, the ambient temperature increases, and a small increase in ambient temperature has many effects on the panel efficiency. The temperature is inversely proportional to the module output power. So at standard test conditions, the solar panel gives maximum efficiency where the temperature should be 25^0C. Thus it is necessary to maintain the module temperature at 25^0-30^0C in order to have better efficiency and performance with higher solar irradiance.

ACKNOWLEDGEMENT

The authors like to thank the National Rice Research Institute, Cuttack, Odisha for providing the necessary set-up for the experiments.

REFERENCES

[1] T. V. Krishna, M. K. Maharana, and C. K. Panigrahi, “Integrated Design and Control of Renewable Energy Sources for Energy Management,” *Engineering, Technology & Applied Science Research*, vol. 10, no. 3, pp. 5857–5863, Jun. 2020.

[2] A. S. Saidi, M. B. Slimene, and M. A. Khlifi, “Transient Stability Analysis of Photovoltaic System with Experimental Shading Effects,” *Engineering, Technology & Applied Science Research*, vol. 8, no. 6, pp. 3592–3597, Dec. 2018.

[3] A. Gholami, A. Saboonchi, and A. A. Alemrajabi, “Experimental study of factors affecting dust accumulation and their effects on the transmission coefficient of glass for solar applications,” *Renewable Energy*, vol. 112, pp. 466–473, Nov. 2017, doi: 10.1016/j.renene.2017.05.050.

[4] K. V. Vidyanandan, “An Overview of Factors Affecting the Performance of Solar PV Systems,” *Energy Scan (A house journal of Corporate Planning, NTPC Ltd.)*, vol. 27, pp. 2–8, Feb. 2017.

[5] B. Patnaik, S. C. Swain, and U. K. Rout, “Effect of Colour Spectrum and Plastic on the Performance of PV Solar System,” *International Journal of Recent Technology and Engineering*, vol. 8, no. 4, pp. 10843–10846, Nov. 2019, doi: 10.35940/ijrte.D4373.118419.

[6] B. Patnaik, S. C. Swain, and U. K. Rout, “Modelling and Performance of Solar PV Panel with Different Parameters,” in *Applications of Robotics in Industry Using Advanced Mechanisms*, Cham, 2020, pp. 250–259, doi: 10.1007/978-3-030-30271-9_23.

[7] H. Wang, B. W. Ang, and B. Su, “A Multi-region Structural Decomposition Analysis of Global CO2 Emission Intensity,” *Ecological Economics*, vol. 142, pp. 163–176, Dec. 2017, doi: 10.1016/j.ecolecon.2017.06.023.

[8] R. Heede, “Tracing anthropogenic carbon dioxide and methane emissions to fossil fuel and cement producers, 1854–2010,” *Climatic Change*, vol. 122, no. 1, pp. 229–241, Jan. 2014, doi: 10.1007/s10584-013-0986-y.

[9] A. Kumar, A. K. Nayak, R. P. Sah, P. Sanghamitra, and B. S. Das, “Effects of elevated CO2 concentration on water productivity and antioxidant enzyme activities of rice (Oryza sativa L.) under water deficit stress,” *Field Crops Research*, vol. 212, pp. 61–72, Oct. 2017, doi: 10.1016/j.fcr.2017.06.020.