Assessment of solar energy based on various meteorological conditions in the Indian climate

A Thesis

Submitted

in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF TECHNOLOGY

In

Production and Industrial Engineering

Submitted by

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July,2022

CERTIFICATE

This is to certified that **Mr. Kartikey Ojha (Enroll No-1500101169)** has carried out the research work presented in this thesis **"Assessment of Solar Energy based on various metrological conditions in the Indian climate"** submitted for partial fulfillment for the award **Degree of Master of Technology in Production and Industrial Engineering** from **Integral University, Lucknow** under our supervision .Thesis embodies results of original work, and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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DECLARATION

I hereby declare that the thesis titled **"Assessment of Solar Energy based on various metrological conditions in the Indian climate"** is an authentic record of the research work carried out by me under the supervision of **Dr. Prem kumar Bharti Professor, Department of Mechanical Engineering, Integral University, Lucknow**.

Dr Manish Madhava tripathi Associate Professor**, Department of Mechanical Engineering, Integral University, Lucknow**. No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

I declare that I have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the thesis. I further certifythat I have not willfully taken other's work, text, data, results, tables, figures etc.reported in the journals, books, magazines, reports, dissertations, theses, etc., or available at web-sites without their permission, and have not included those in this Master of Technology thesis citing as my own work.

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ACKNOWLEDEMENT

I would like to express my deep sense of gratitude, respect and honor to my supervisor **Dr. Prem Kumar Bharti,** Professor, Department of Mechanical Engineering, Integral University, Lucknow, and my co-supervisor **Dr. Manish Madhava Tripathi**, Associate Professor, Department of Computer Science and Engineering, Integral University, Lucknow for his illuminative and precious guidance, constant supervision, critical opinion and timely suggestion, constant useful encouragement and technical tips which has always been a source of inspiration during the preparation of dissertation. I consider myself extremely lucky to be able to work under the guidance of such a dynamic personality.

I would also like to thank the rest of dissertation committee, my dissertation Incharge **Dr Mohd. Anas** Associate Professor, Entire Faculties and staff of Department of Mechanical Engineering for their supports, encouragement and providing me the opportunities while working on this exciting research.

I will be failing in my duties if I miss to express my profound and deepest sense of gratitude to my beloved parents and other members of family and friends for their keen interest in my studies, immense support and encouragement , without which it was impossible to complete this dissertation.

I also place on record my sense of gratitude to one and all who directly or indirectly. Have lent their hand in this thesis.

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ABSTRACT

Solar energy these days are in increasing demand as fuel prices are increasing day by day. Energy generated from the solar system is green and carbon free energy. In countries like India, it has very promising future due to abundant of planer regions. In planer regions sunlight directly falls over the surface and has high direct normal irradiance, (4-7 KWh per square m) which can be harnessed greatly for the production of energy using PV(photovoltaic) or PVT(photovoltaic thermal) methods.

Indian government has established comprehensive solar resource tracking cum meteorological station in the guidance of Ministry of New and Renewable Energy under the Solar Radiation Response Assessment (SRRA) project in 2011. In 2022, India is producing 30 GW of solar energy and become the 5^{th} largest solar energy producing country surpassing Italy recently.

Different metrological parameters like solar radiation, temperature and wind speed are the prime factors affecting the production of solar energy.

In this thesis we have divided our work into two parts.

In first part we have discussed the effect of metrological factors over the efficiency of solar panels. For this, we have selected 5 places to install different sensors to record these weather parameters based on Campell conditions. We have taken data of half month from 26 Feb2022 to 7^{th} March 2022 from these places and monitor the impact of changes in weather conditioning on the solar energy. Significant differences in insolation were found when comparing satellite and ground-based measurements. At some sites, it was found that the average deviation of solar isolation for a period of 15 days was 40% from the satellite base observation but for the same period of time this deviation is less than 12% when measured from the ground base. The data on wind speed and direction also has been collected from the local weather station.

All 5 experimental roofs were equipped with solar panels. The monthly and annual output of the solar system was modelled using various simulation processes. Using a variety of state-of-the-art technologies, a solar power plant with a peak power of 8.3 kW can produce 9.03 MWh per year, and with the addition of thin-film technology it can reach 9.67 MWh per year. It can be concluded that the use of environmentally friendly technologies can lead to low cost development. It has been concluded that sometimes multiple implementations are needed,

such as simulating solar power performance. In this study, we also describe a set of measures for the procedure to bridge the gap in insolation installations.

In second part we have taken weather data from repository https://data.open-power-system-data.org, and analysed variation of different metrological data over the period. Then find some collinear relation between these data, so that it can be applied for regression algorithm of machine learning for prediction of solar energy by solar panel besed on these identified weather factors

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NOMENCLATURE

AASC	:	American Association of State Climatologists
CoE	:	Center of Excellence
CFD	:	Cumulative Frequency Distribution
IEA	:	International Energy Agency
CFD	:	Computational Fluid Dynamics
EPA	:	Environmental Protection Agency
Eppley PSP	:	Eppley Precision Spectral Pyrometer
FTP	:	File Transfer Protocol
GLOBE	:	Global Learning and Observation to Benefit the Environment
ISS	:	Integrated Sensor Suite
METAR	:	METeorological Aerodrome Report
MIDC	:	Measurement and Instrumentation Data Center
N,E,S,W	:	North, East, South, West
NASA	:	National Aeronautics and Space Administration
NOAA	:	National Oceanic and Atmospheric Administration
NREL	:	National Renewable Energy Laboratory
PC	:	Personal Computer
PV	:	Photovoltaic
RH	:	Relative Humidity
SIM	:	Sensor Interface Module
SolarGIS	:	Solar Geographic Information System
SPA	:	Solar Position Algorithm
SSE	:	Surface meteorology and Solar Energy
USB	:	Universal Serial Bus
CSP	:	concentrating solar power

LIST OF SYMBOLS

α	Elevation Angle
σ	Standard deviation of wind measurement
c	Weibull Scale Factor
c_t	Clearness index
$f_i(c_t)$	Frequency dependent from clearness index
$f_{weibull}(v)$	Weibull distribution at certain speed
G	Solar isolation
G_o	Solar isolation without any distribution
H_o	External radiation
i	Index
k	Weibull shape factor
n	Quantity of intervals
v	Wind speed
$\bar{v}$	Average wind speed
X_i	Cumulated frequency at *i*
X_n	Total Cumulated frequency
$x_i(c_t)$	Occasion of $c_t$in the given interval

CHAPTER 1

INTRODUCTION

To solve the worldwide crises associated with electricity demand all the countries of the world are considering the sustainable method to supply electricity using renewable strength resources. One extra purpose to divert a wide variety of researchers' interest closer to the renewable sources of energy is its availability in abundant quantities which can be permanent resources. It is roughly calculated that the energy requirement will grow27% from 2022 to 2045. Non-stop urbanization and commercial development enlarge the demand for strength in India. to address this emerging demand in a balanced way Indian authorities proposed a separate and independent ministry for opportunity power sources. This empowered to make aware and facilitate the various ways to apply the clean strength in rural in addition to in city regions of the country modern-day's electricity demand is fulfilled by using the non-renewable assets of energy as fossil gasoline, that's restrained in quantized, and the use of these assets additionally have many harmful impacts on the surroundings. a fine alternative to these issues is to apply the renewable assets of electricity. As per global data, the highest increment in energy demand is found in the non-OECD nations having lower economic standards and higher growth rates in population, especially China and India. India also emits a huge amount of greenhouse gases in comparison to its economy and industrial development. The average increment in the use of fossil fuel was 5.7% per year from 1950, and India is one of mostCO_2 emitting countries in the top five (Boden et al., 2011). As per recent data from the Ministry of Environment, Forest and Climate Change the energy sector emit 71% of total GHGs emission in India. On 30$_{th}$ June 2020, India touched the milestone of 35.12 GW Solar installed capacity which is a good share of the total installed capacity of 371.977 GW, on the other hand, India has reached one more milestone to produce clean energy by producing 35.7% of total installed capacity of 371.977 GW by the mean of renewable energy sources including hydro plant, this all shows that there is a great possibility to explore the solar energy production process if a tireless approach of researchers gets a chance to explore it with the government's support. Indian lands get 5000 trillion kWh per year from Solar radiation. Nearly 2.4 hectares area is needed for a solar power plant to produce 1 MW of power.

In the Paris convention 2015, a promise was made by 187 countries (Contributing 97% of total pollution due to the use of fossil fuel) to reduce 2 ^{0}C in the current increasing rate of global warming. To get this targeted achievement solar energy to identify as the best option as an alternative to reduce the consumption of the current energy sources. Keeping in mind the global demand for solar energy, the various working in the field of solar energy expect a huge growth rate of 24.6%, and the investment forecast is around 422 US dollars by 2023 (Vedachalam, 2018). Very less amount of GHGs emitted due to the use of solar energy when compared to non-renewable energy sources. Future crises in the availability of fossil fuels, increasing global warming, and harmful impacts on the environment due to the use of fossil fuels are the main driving force of emerging development in the field of renewable energy. Currently available data of overall power generation by solar energy in India is 34627 MW shows a good opportunity for development in the field of solar energy utilization. The going on deployment of the solar power stations in India helps in decarbonization, a huge amount has been invested in this sector due to which India become the emerging leader to implement the Paris convention. A lot of possibilities are available to utilize renewable energy in many poor and developing countries to fulfil their energy demand. All countries are working to be energy potential countries to be a part of the current growing economy, hence the use of an alternative source of energy become essential to get these targets for the prospective of less harmful impact on the environment. Researchers are continuously working to develop new techniques to better up the cost and efficiency of the present solar system based on all available knowledge in this field. Excellent growth in the use of renewable energy sources has been observed worldwide. It found that each country has an aim to produce 33% of total energy by the mean of renewable energy sources before 2040. Solar energy is a prime source of renewable energy sources. To fulfil this aim Indian government is continuously working in this field and deploying solar energy. For quick action a project Solar Radiation Resources Assessment has been started, mainly motivated by United Nations Development Program in which a continuous improvement target for 2020-2025 has been decided.

It is nearly the same as a thermal power plant if we concluded the mining area, water storage area, and the area which is used for ash disposal, the same area is also taken by the hydropower plant if included the submerged area of the water reservoir. There is much space in India which are currently unproductive like barren lands that can be utilized by installing solar power plants. A plant that has a total of 1.33 million MW capacity, can be installed on .98% of the total land area of India, this area can be found in many parts of the country as unproductive areas, which are potentially fit for the solar energy production. To elaborate the research in solar energy and starts an industry-academia partnership by collaborating with Renew Power Ventures Pvt Ltd. This Centre of Excellence is also funded as sponsored project; one of these is the centre of excellence in climate modelling, which is primarily focused on skilful simulation and projection of the Indian climate.

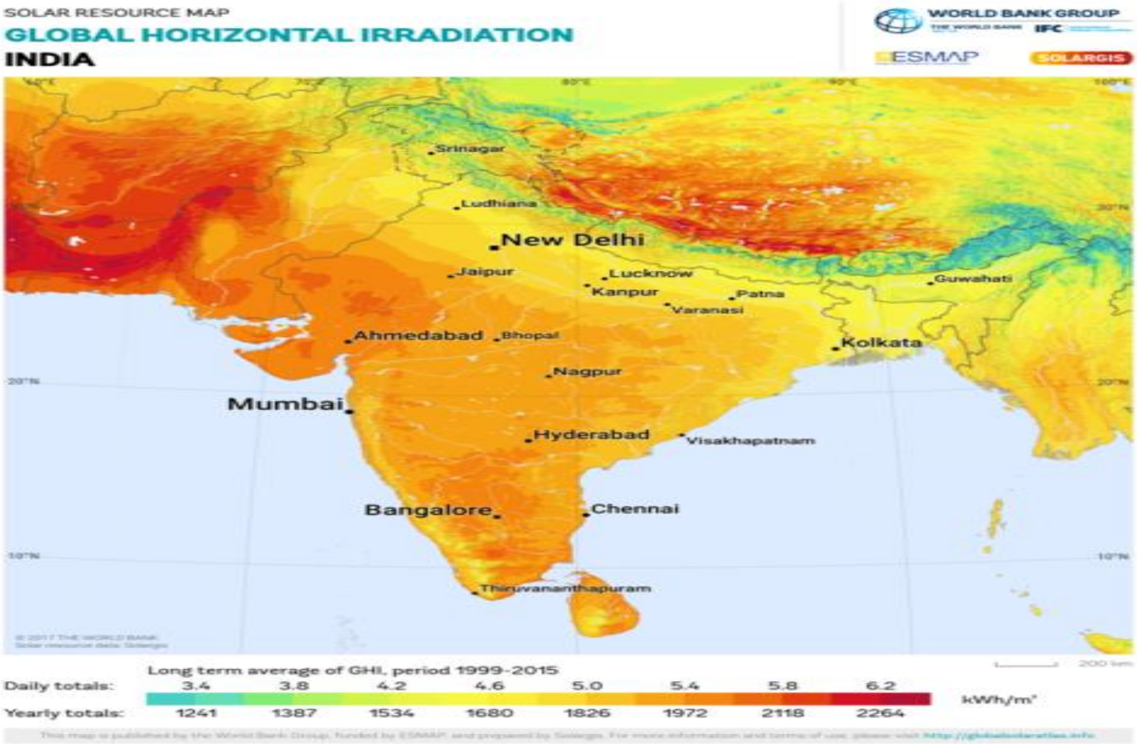


Fig. 1.1 Global Horizontal Irradiation in India. Source: Global Solar Atlas

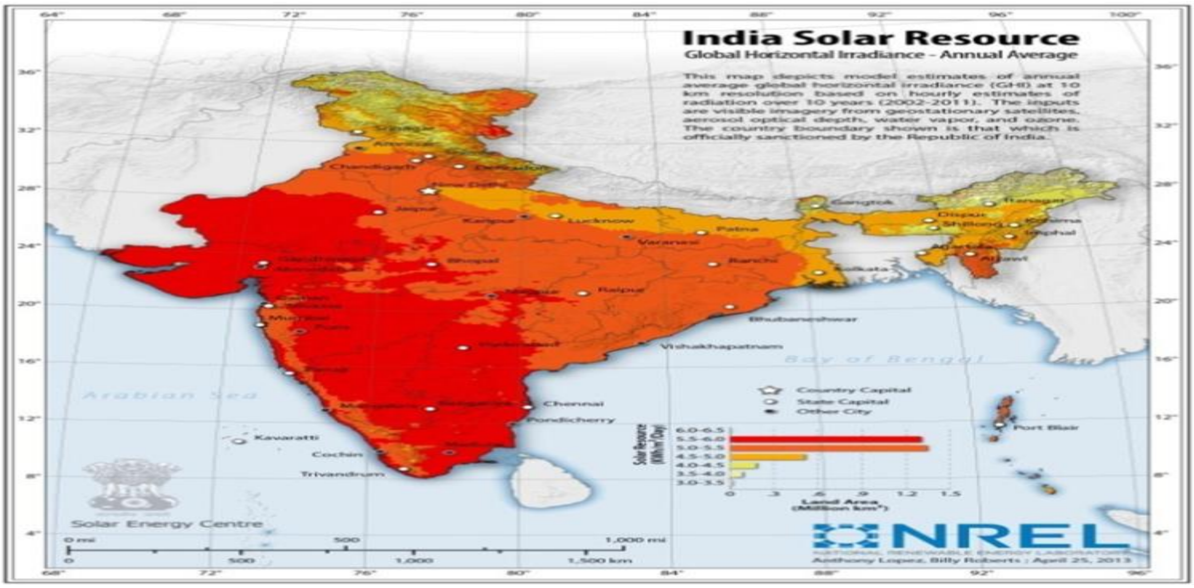


Fig.1.2 Global Horizontal Irradiance – Annual Average. Source: National Renewable Energy Laboratory, U.S Department of Energy..

Mainly photovoltaic (PV) is used to convert lights into electricity utilizing semiconductor material. This pandemic situation due to COVID-19 affects very badly the faster growth of the PV installation, According to the current report of IEA the PV installation reduced by 23% related to installation done in 2019. IEA also predicts that the total collective PV deployment in 2022 and 2023 will be 19 percent less as forecast earlier. The solar and weather assessments are required to evaluate and forecast the energy generation quantity by the installed PV. Installation of a personal setup is costly and complex but it is essential to modify the system according to your own need. The data relating to weather humidity, amount of solar radiation, and fluctuation in temperature are taken from the center of excellence for non-renewable energy. The daily weather data like temperature, wind speed, wind direction, and solar insulation are found from Indian Meteorological Department's surface observatory situated at the Safdarjung Airport terminal which validates the local measurements taken from its setup.

CHAPTER 2

LITERATURE REVIEW

For a maximum generation of solar power from a solar power station it is very essential to choose a location in which more solar radiation is achieved. This location is not depending only on basis of the high intensity of solar radiation it depends s many parameters like duration of solar radiation exposure, wind speed, wind direction, temperature, humidity, rain, and some other environmental conditions. To increase the productivity of solar energy plants and reduce the cost per MW generation many researchers are continuously going on. Eminent researchers, working in this field shifted their attention toward finding the technique to increase productivity and reduce the cost of production by finding a way of transforming solar energy into various forms of energy. For this purpose, it was found that the appropriate climate dimension as per the various weather data which was found from weather stations is the most effective way to increase productivity, but research is still going on the aspect of weather conditions. The installation cost of the solar plant is high so it is also needed to make correct future weather information for the necessary measures, implementation of which is required for energy generation and process to fix the problems related to environmental issues. The solar cell productivity depends on many factors like humidity, rain, temperature, etc. that's why accuracy in the forecasting of these parameters helps to get an idea about the season, and location to expand the solar energy production and decrease the cost of production, which certainly boost the economy of the country if the production is done on a large scale with the help of proper forecasting of weather condition. Because of it, a decision can also be made that what is proper timing to shut the energy power station and engage the employee at the other station which is suitable for energy production at that time.

To find the correct site, weather data gives the best idea of financial returns from a solar power plant. The productive operation, proper forecasting, and maintenance can surely increase the efficiency if all mentioned operations are collectively implemented with weather measuring data.

Various studies to investigate the impact of many parameters on solar stations and to find the correct understanding of weather evaluation to decide the initiative which has been taken to increase the productivity of solar power stations.

Gueymard and Myers[1] discovered that the solar power region requires help from radiometric measurements for lots of statistics to install a proper layout as well as for monitoring power stations and assessing of setup model. It was also found that instrument uncertainties give wrong data which affects the measurement process as well as radiation assessment. This study also assures that the previous studies in which it confirmed that majorly applied pyrometer underestimates global radiation, especially in the winter season, till tan correct measurement is done. The importance of forecasting from the transportation methods to errors in input radiation data is an exhibited.

Purohit and Purohit[2] did a Techno-financial survey for concentrating sun strength era. They defined The Jawaharlal Nehru national sun task of NAPCC introduced via Indian authorities with the intention to enhance the growth and sell of solar strength for power production and other initiative with which the solar aggressive with fossil fuelled strength device. With many purposes as (i) Policies for power generation include that 20000 MW solar power units will be deployed till 2022. (ii) Provide funding and other government facility to the industry which are working in the field of solar power production (iii) Promotion of off grid system and cover a mile stone of 1000 MW, 2000MW till 2017 and 2022 respectively (iv) Identify 15 million m^2 and 20 million m^2 area of thermal collector has to be deployed by 2017 and 2022 respectively(v) establishing 20 million lighting systems based on solar system by 2022. A prior assessment in the aspect of technical as well as economical for concentration solar power technology is made in this study. Techno-economic effectiveness of concentration solar power technology for

Indian climate is assessed by PS-10 and ANDASOL-1 becomes the base for present investigation. Simulation of these systems has been done for various Indian locations. It was found that the CSP technologies are beneficial in the north-western part of the country in the financial aspects. It concluded that the sites with yearly solar radiation 1800 kWh/m^2or more than it, mainly suitable for installing this CSP systems. The finding of this study can be utilized for deciding of location for short-term use of solar energy in the aspect of concentrating solar power production in India.

Pal and Devara[3] carried out wavelet-based spectral investigation for long length of optical characteristic of aerosols located via lidar and radiometer tracking in Western India. A detailed observation of statistic for yearly as well as inter annual of lidar and radiometer found from aerosol distribution was done to found the impact of various seasons and weather conditions at the location where investigation is performed in western India. The effect of urbanization at the long duration variation at the lider measurement of aerosol loading was also found. It was done by lidar observation and a set up made for Pune city, which considered population as well number of vehicles and industries of this city.

Shrimali and Rohra[4] mentioned the diverse tasks carried out thru JNNSM to evaluate the development which has been achieved in solar electricity discipline to reform the energy quarter. In this study the details of problems faced during the implementation is also discussed broadly.

Purohit et al.[5] assessment of concentrating sun electricity era effectiveness in North-western India, this region of the u.s.a received biggest sun power with helping meteorological situations inside the thing of CSP, presently a massive waste region is likewise to be had in this part. Concentrating solar power (CSP). It was found that future sites having lower DNI magnitude will become economically feasible using new techniques, new materials.

Padmavathi and Daniel[6] perform evaluation to analyze 3 MWp grid connection of photovoltaic electricity plant in Karnataka country India in accordance IEC wellknown. using observed data. Seasonal and daily basis variation of SPV plant result is presented for observed data done at each five minute time interval. The SPV production according to load variation curve is observed. Standardized execution parameters of the plant and similar variables of other plants were compared. Finding of the power station is validating the report available for other countries.

Kumar et al.[7] performed subject evaluation of sun radiation stations in India, a detailed evaluation of total functioning energy stations for twelve months period prepare a listing of problems and inaccuracy observed for the duration of functionality. From the findings of 51 stations it concluded that many station working very well but rest are required serious improvement. Working of quality control system is very essential to find inaccuracy in performance of stations. A prime conclusion was made that continuous simulation is required to enhance the performance of a station. A basic gap filling procedure for solar energy is also described in this study. The procedure is applied on whose outcomes represent a mean bias of ca. 3 % over GHI, DNI and DHI over all types of gaps.

Chandel et al. [8] performed Wind energy evaluation of 12 specific positions in western Himalayan part of India for its effective utilization. This investigation is to be done for evaluation of effectiveness of wind in the Himachal Pradesh to find out effective location. WEPF technique is apply to evaluate the wind effectiveness of 12 different places at different territories and climatic regions utilizing wind data form 2008 to2012. Weibull and collective wind dispensation, Weibullfacts as well as Wind Power Density were found for these places. The maximum wind velocity is seen in hot season and minimum cold season in this location.

Ruiz-Arias et al. [9]evaluated solar resources, in order to optimize the combination of the net and ground-based observation of the solar radiation. Correct size of the solar power aid is of fundamental importance for the multi-faceted development of a solar power plant. This assessment is mainly carried out by radiometric stations. However, from the regional to continental scale, the satellite methods are the most suitable for you. Solar radiation is presented, with the aid of the numerical weather forecast models, it is more efficient than that of a satellite in constant time. On the other hand, the grid-based detection of the sunlight, radiation, or of a satellite method, or by using the still gives biased estimates, which have significantly higher values. Therefore, it should be improved in order to make use of such income to the values used for the calculation of solar energy, especially in the case of calculations on the basis of these. This technique is based on the optimal interpolation method for the enforcement of the radiation pattern; it is frequently calculated using the corresponding radiometric observations. The performance of this system was determined with the help of integral calculations made on the basis of these, with a 10-kilometre area of the world, and the direct monthly data on exposure for a period of 10 years from 2003 to 2012. In this technique, the value is adjusted in the probability of an error of measurement of the soil analysis, and if there are several observations to be made to fix them. The results will provide you with advice that is, the average distance between the observation points, from 100 to 150 miles and can lead to the objective grid estimates.

Sivarasu et al. [10] A study in preparation for the implementation of the project on the basis of renewable energy sources in terms of the interests of consumers in India, taking into account the ability of the body. The results of this analysis indicate that the site will be taken as appropriate to the glass, and solar resources, and more resources to increase the power value, in MG. We will advise you of the potential for solar photovoltaic (SPV), a turbine, hybrid models and their suitability in relation to the empowerment of individuals in India, which is the empowerment of the country, and to reduce the use of fossil fuel-based energy. The results of this study show that the main problems and their solutions in the design, development, and implementation of the MG projects in India.

Chauhan and Saini [11] including the comments of the joint use of a small hydroelectric power plants, such as biomass, biogas, solar energy and small wind turbines, and by way of a single system of technology is aimed at summarizing the technology, which is based on the site in a given area. A methodology for the assessment of the level of demand and the resources available in a given area is being developed. We have also discussed the many obstacles and issues that shape the way in which the system is to be implemented.

Gherboudj and Ghedira[12] for a overview of the capacity of sun electricity inside the united Arab emirates with the help of far off sensing of the Earth, in addition to the climate statistics to the system. The innovative cards are used to describe the suitability of the land for the use of solar energy (PV and CSP) in the United Arab Emirates (UAE). The proposed maps are produced by the combination of solar radiation maps, taking into account the impact of the land, the limits and under the conditions. Remote sensing, weather forecasting, modelling, and geographical information system (GIS) to provide all the various aspects of the calculation and verification of the data with a high temporal and spatial resolution. In fact, these data have a high accuracy for a better understanding of the extent of the extension at any of our locations. The results of this study, it is aimed to improve the efficiency of the use of search tools, land, map,, United Arab Emirates, dust and moisture in the air and the temperature of risk maps, and, as a result, the degree of the country perfection-index for both photovoltaic and CSP power plant equipment. The obtained results show that the photovoltaic power stations are more convenient for the United Arab Emirates, in comparison to CSP plants.

Mentis et al. [13] Geospatial exploration of wind energy technological and economic power in India. The current study focused on coastal wind power and concerns in providing techno economic power estimates based on wind energy technologies. Economics and geographical wind farms are structured and used as a major step-by-step guide for Geographic Information Systems (GIS) views. The cost of wind power is estimated geographically. In this study it was found that there are many areas with high wind yields every year, such as Rajasthan, Andhra Pradesh and Gujarat, while Goa and other areas showed very little or no energy. Electricity generation costs fall between 57 and 100 USD /MWh, making wind power competitive in India. Murthy and Rahi[14]Did a preliminary assessment of wind power capacity in a coastal area in the north of Andhra Pradesh, India. The Wind Potential (WPP) . Currently, the plan is only in the low-lying areas, no attempt will be made to reach a higher altitude. Instagram allowances are used to calculate the value of SILVER to that of estrogen. This study provides an insight into the development policies pursued by the energy professionals along with researchers in the related field. This analysis makes use of the capacity factor (CF) method and the Weibull model. For a very long period of time, the daily wind speed information for the 32-year - (1983e2014), at a height of 10 m, and is derived from the NASA web site. Finally, the comparison of the wind power density (WPD), is located after the completion of these two models was statistically detected, monitored, and reported on in Chapters 5 and 6, respectively.

Müller et al. [15] Worked on the combination of a map and a thorough approach to creating a custom solar roof. In order to have a consistent set of data, the value of 51, on the basis of measurement stations in the country has been used to obtain the correction factor at this stage. At the same time, one of the other 61 stations was used to compare the long-term, search, maps, and the monthly baseline data. There are multi-year averages, the average of the values for each month of the year, as well as the standard deviations for the different radiation components.

Jamil and Akhtar[16]carried out a sociological study carried out to compare the performance of the diffuse solar radiation model, and the sky is the indicator, additionally the time in sunny humid-subtropical climatic zones in India. In this analysis, the solar radiation assessments have been carried out over a period of three years, from 2013 to 2016, in the city of Aligarh, Uttar

Pradesh, India (27.88°n, 78.08°east longitude). According to the data and the global mean value is 21.01 MJ / m2, and the beam is 13.40 MJ / m2, and the scattered light from the sun 7.61 MJ / m2 per day. It has been found that a good agreement is observed in the ground-based measurements and satellite data. Modelling of diffuse solar radiation has been carried out depending on to the sky, and the index is the relative time from the rays of light. In this study, 42 of the new models, up to and including category 6 were modelled. The proposed models are also supported by the models are available in the literature. The models were evaluated in terms of efficiency and in terms of the top ten most commonly used statistical indicators. It was concluded that a model with two input variables, which results in better performance compared to a model with only one variable.

Vedachalam[17] carry out the assessment for decarbonisation limits of sun electricity for the strategic Indian strength production place. The y described that emphasizing exploitation of solar energy can reduce hydrocarbon imports and emissions; this is need huge investments. A clear and sustainable approach requires executing the strategies need for long period decarbonisation.

Pereira et al. [18]to develop a model of the solar radiation with the help of an autonomous communication techniques for the weather research and forecasting (WRF) system. This research is mainly done in order to improve the value and the value of the sun's rays, as well as the differences in the results due to the Weather Research and Forecasting (WRF) model with the help of the new forms of Autonomous Communication Process (OCP). OCP has the facility of clear-sky environments, including the effects of the atmospheric composition, which changes with the clear-sky model of the impact of the cloud will disappear, and the decomposition method, in order to properly distinguish between the global solar radiation. The measurements were carried out over a period of up to one year. A simple test has been carried out in order to explore a variety of configuration options. Two of the aerosols, databases, and three clear-sky models, and the two of cloud attenuation corrections based on the clear-sky index is to be considered as well.

Yeom et al.[19]the Study of solar energy and wind power in North Korea is in the details. To estimate wind resources, means of production, the model statistics (MOS) have been integrated with the post-processed variables of the Local Data Assimilation and Forecasting System (LDAPS). In the estimation of wind energy, the wind speed is provided by a digital weather (???). It was found that the various regions of North Korea, it can be an obstacle for the further development of the infrastructure, renewable energy sources, this is the big mean and solar energy, and energy is results explain the significance of the potential of renewable energy sources in North Korea.

Rehman et al.[20] Did the evaluation for solar capability for public bus routes of solar buses.

The clear sky and systems close to the street allotted by using automatic image processing set of rules that turned into using on this study. After this process the images deployed for solar assessment to found the information of the average solar irradiation on this route. Then a comparison in the energy requirements for an electric bus and available energy from solar radiation is made to find out that what part of this demand can be utilized by available solar energy. For this purpose, a public bus route in Invercargill (New Zealand) was investigated. A fisheye camera was setup at the roof of a bus to take the images. It was concluded that 8.5% of total electric demand to run the bus can be fulfilled by solar panels which was installed on the rooftop. Pinto and Stokkermans[21] Investigates various floating sun technology on the premise of diverse case examine. want of Floating sun generation (FPV) got here in the photograph due to scarcity of land, lower of performance at excessive mobile temperature, particularly due to intention of decarbonize. The purpose of this investigation was to fill the gap between the expected performance for FPV systems and the outcomes from simulations of production of power. It was found that high efficiency is depending on technologies as well as on the location.

Sumair et al. [22] evolved a way for Weibull parameters estimation and evaluation for wind efficiency. in this statement a technique named modified technique of moment (MMOM), compared with distinct techniques first strength sample element technique (EPFM) and method of moment (mom) for the evaluation of wind ability in Punjab has been executed.

Kumar [23] Explore solar energy from satellites, in numerous regions of India. The manifestations of solar variations are analysed in this study. In this study satellite imagery was used for solar data retention. Observations of solar panels including generalized irradiance (DNI) and global horizontal irradiance (GHI) provide an opportunity for information on energy efficiency. This view shows the map of the southern states of India in resolving the 100 km2 grid. The Karnataka and Tamil Nadu regions have been found to be the best applicants. The findings of this study have a bearing on the future of local distribution at the national level. These studies might be of fantastic assist to better making plans in this field.

Kapen et al.[24]made a comparison of ten-digit strategies to calculate Weibull's parameters for exploring wind energy which is a different high-potential (AMLM) method, the equitable energy method (EEM), a highly modified alternative (MMLM), high-potential (MLM) , energy pattern factor (EPFM) method, Mabchour method (MMab), graphical method (GM), timing method (MoM), Lysen art form (EML), and Justus (EMJ) art form, Weibull flexibility by the power of the wind. Made with the help of wind speed data downloaded from the weather department. Statistical observations show that MLM exhibits the best strength in all simulation tests, with reduced order EEM, EPFM and EMJ. According to the error number EEM has a small error.

CHAPTER 3

OBJECTIVE

The ultimate aim of this study is to yield weather data for solar energy evaluation with the help of solar radiation sensors. There is a prime question whether the data are correct or not, which also to be check. This is useful to find the best location for a solar power installation.

There are various available methods to provide weather data and solar data like weather station working on satellite reports and ground measurement. A major interest of this research is to find the comparison in the data which was found from the own station and from various ground report as well as satellite report and find the reason of differences in data.

Our next is to predict the solar energy based on only parameters, radiance on ground and top of the air and temperature.

CHAPTER4

WEATHER CONDITIONS

To have a good idea of the many challenges and situations encountered at the time of this review.

4.1 Centre of Excellence for renewable energy

The association setup and calculations were performed at the CoE located in New Delhi. The synergistic effect of different parameters on force generation is also detected here with different instruments inside the golden average of excellence.

This is also facilitating the research support to researchers who has area of interest in same field. A proper support is provided to explore this area with provide all the facility which is available there as well as a proper guidance to trickle any problem.

4.2 Regulatory procedure for grid linked PV in India

India's TPV installed capacity reaches 34627 MW (April 2020). maximum set up became presenting facility to affect the rural regions or diverse government reliable buildings. That’s why we have faced a lot of problems to get information related component cost, regulation process, tariff feeding, long term evaluation.

Table4.1 PV hooked up capability in MW For diverse applications

Utility	**31st july 2021**
Terrestrial solar power	27945.29
rooftop Solar power	2,230.10
Standalone Solar power	920.20
TOTAL	31,112.41

There are various companies provide PV systems in India like Tata Power Solar Systems Ltd, Ampules Energy Solutions Private Ltd,Icomm Tele Ltd etc. There is seen the cost different in production of electricity in various states of India, prime cause of this increment in the cost is transportation of Diesel and gasoline. Below the graph is shown the cost difference in the production of electricity.

Table4.2 fee of energy of various place from grid gadget

Location	Electricity cost per KWh
J. & K.	1399 USD/ KW
H. P.	1326 USD/ KW
U. P.	797 USD/ KW
Bihar	1020 USD/ KW
M. P.	794 USD/ KW
Karnataka	782 USD/ KW

Renewable electricity tariffs are determined using a variety of pricing players based on the ease of grid location flexibility. Pricing additionally relies upon on voltage intake. If government apply any official feed for tariff in PV it may be around 1005 USD/KWh. Below the table 4.3 provide an unofficial record for tariffs if PV installation is done in 3 phase

Table4.3 Pricing factor in different regions of India for PV feed and tariff

Feed Voltage (For 3 phase)	Feed Tariff (Voluntary payment)	Price Factor
At Low Voltage 450V	$F \times R_p$ 1020/KWh	F= 1 for New Delhi F= 1.4 for Uttar Pradesh

Medium Voltage 25kV	F×R_p 680/KWh	F= 1.6 for Himachal Pradesh F= 1.5 for Jammu & Kashmir

Today, a generation of polycrystalline and monocrystalline solar systems has developed. but we are not using a very important generation in this field to install skinny films in India because there is a problem. cost of a panel trip RS10000/ Weak. This cost reduction also increases our volume. The cost of the inverter depends on your needs. The DC to AC converter with 2300W is almost Rs 15000. Even around RS 7/W. For the convenience of calculations, we have considered that the network is connected using an inverter of equivalent cost. below, Table 4.4 provides an estimate of the overall price.

Table4.4 Pricing factor in different regions of India for PV feed and tariff

Component	Price: RS/W_{peak}
Panel	75-100
Converter/ Inverter	70
Cable, Transport and Installation	75

4.2 Technical Arrangements

4.2.1 Weather Station

Principal recognition in this have a look at is primarily based at the raw association of the weather station “Vantage Vue” of “Davis contraptions”. that is combination of numerous sensors for measurements

- Radiation sensor
- Rain Outlet
- Temperature Sensor

- Humidity Sensor
- Wind Direction Sensor and Anemometer
- Barometer

Fig. 4.2 Set up Weather station has been installed at the top of the Building (top most left)

This unit is taken because it is latest model of 2022 which gave a result with a good accuracy and in an affordable cost at RS 28000 in Indian market. A good feature of this setup is that it is having a big range of wireless transmitter. To get the data a free radio band (872.0-880.8) is used on which this station sends the data. Its range can be expanding up to 350 m in the line to side. The range from the wall is set up 70m to 140m by the DAVIS INSTRUMENTS which is manufacturer of this weather station.

The data is collected to a Sensor Interface Module (SIM) from the entire sensor, where collection of data then the transmission of this data is sent at required place. All sensors should be in single setup like the top left figure of 4.2.

The data is sent to the PC which is connected to the receiver to get all the data. The data can be taken in seven different timings, due to some reason if the PC get off then receiver can store the data this receiver can be store up to 3000 data. Data is maintained and observed at 32 variable parameters like (Date, time, humidity, wind direction, atmosphere temperature.). Table 4.4 depicts the correlation of sampling intervals and record timing.

Table 4.5 Sampling gap and recording timing at the receiver

Sample Interval (minute)	1	10	20	40	80	160	320
Record Time	45	15	20	31	56	207	250
	Hours		Days				

4.2.1.1 Solar radiation sensor

It is a major part of this weather station that has important applications for this station. It is located next to the rain gauge. It must be in a horizontal position; it has layers of air in this shell that provide convection cooling.

Fig. 4.3 Solar Radiation Sensor

It has photodiode having the cell, in this setup a amplifier situated which convert the current into the voltage upto the 2.5 volt. Table 4.5 depicts data of this sensor

Table 4.6 **statistics of the solar radiation sensor**

Technical Data for Solar radiation sensor	
Resolution and Units	1 W/m^2
Range	0 to 2000 W/m^2
Accuracy	10 % of total scale
Drift	Up to ± 4% per year
Cosine Response	±3% for angle of inclination from 0^0 to 75^0

Temperature Coefficient	-0.15% Per^{0}C (-0.067% per ^{0}F) Temperature reference is 25^{0}C
Interval for Update	60 Second to 120 Second
Current Graph data	Instantly, Hourly, Daily, Monthly
Historical data	Hourly Average, Daily
Alarm	High Threshold from Instant Reading

4.2.1.2 Temperature sensor

It is located under the rain collector. it is based entirely on PN junction diode, sampling every 10 to 12 seconds, can be degree -40^{0}Cto +60^{0}C. In Fig. 4.4 the temperature variation is shown with respect to time.

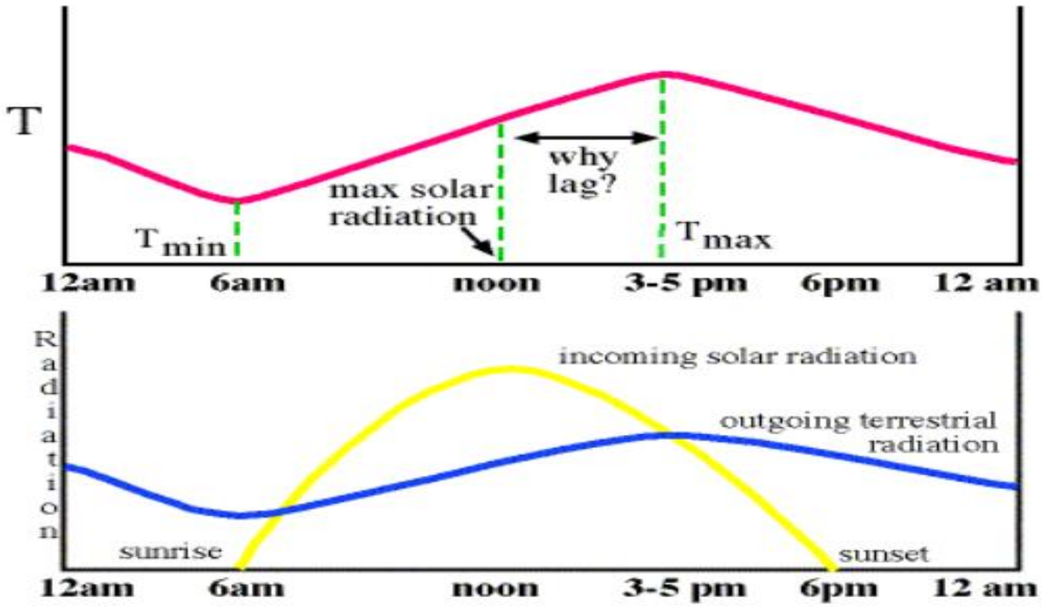


Fig 4.4 Accuracy over temperature trend for Davis temperature sensor

4.2.1.3 Moisture sensor

Relative humidity is measured with this sensor. This sensor can measure up to 100% RH. The time it takes to update is 50 seconds to 1 minute.

4.2.1.4 Pressure sensor

It measures pressures up to 1200 mbar with an accuracy of ±2.0 mbar with an update interval of 50 seconds.

4.2.1.5 Wind direction sensor

With the help of the spoiler, the path of the wind can be determined. Using a potentiometer, resistance is formed in the path of the wind. It updates in 2-3 seconds; due to its quality it becomes the fastest sensor in the whole system.

4.2.1.6 Wind speed sensor

Wind speed is calculated using a magnetic suction cup and suction cups. The shaft rotates once when receiving an impulse. This sensor also has the same 2-3 second update time as the wind route sensor

4.2.1.7. Rain sensor

It measures precipitation using an inclined bucket and a rain-collecting cone with an area of 250 cm2. every 0.2 mm of precipitation suggested reading, all stats are sent to SIM. update time is 20-25 seconds**.**

Fig 4.5 Rain Gauge

Changes in the accuracy of rainfall are shown in the table. 4.6.

Table 4.7 Rain sensor accuracy

Rain Rate	Accuracy
Up to 60 mm/h	±5% or 0.3 mm
60 mm/h – 120mm/h	±5% or 0.4 mm

4.2.1.8 Limitations

Since semi-experts are not as accurate, long-lasting, and powerful as are used by many meteorological services as they may use very expensive and very specific equipment that is not feasible in weak financial conditions without, we use**.**

CHAPTER5

Installing the Weather Station

For the experiment purpose, we have installed our own weather sensors at 5 locations shown in Fig 5.7 all near Delhi. The material used for study of solar panel is as under:

Max power 10 W_p

Max power voltage 19.25 V

Max power current 0.52 A

Short circuit current 0.55A

Open circuit voltage 22.5 V

Maximum system voltage 600V

Dimension 350mm X 250 mm

Solar type loom solar

The above solar panels were installed on the roof at 3.9 m of height and were investigated for 15 days. The current and voltage readings were taken with a digital multimeter. Other variables like temperature humidity were taken from google.

Following parameters can be calculated using their standard formula

Power (P) = Current (I) X Voltage(V)

Efficiency(E) = (P/A(1000W/m^2)) x 100%

Intensity of panel I_p =P/A (Wm^2) where A is the surface area of panel

Due point temperature T_d = T –((100-RH)/5)

5.1 Methods

5.1.1 Identify a proper location

Various considerations need to be made in selecting the appropriate location to install the weather station. The advice in the "Installation Manual" can be consulted from which we have an idea of the environment to avoid for installation and the proper location to install this station. We have selected 5 locations to install it and the conditions have been classified for all sites. Identifying weaknesses is also important in discerning the optimal situation as well as the current situation.

We get an idea from literature survey for identify the proper location. It should be assured that there should not be shading at the timing of solar measurement from stating the day timing to the end of shining hours. From literatures we have find the idea that near the equator chosen location should be high. Various points and table 5.1 is found from Campbell Scientific.

Table 5.1 Sensors location instructions

	Association	Elevation from floor
Wind	A.A.S.C.	3.9 m ± 0.2 m
	E.A.P.	12.0m
	W.M.O.	12.0m
Temperature with relative	A.A.S.C.	2.1m ±1.26m
Humidity	W.M.O.	1.4m to 2.4m
	E.A.P.	3.0m
	A.A.S.C.	1.4m ± 1.4cm

Rain	W.M.O.	44.0 cm min
	E.A.P.	44.0 cm min
	Non objects ≥ 7^0 from the horizontal	
Solar Radiation	≤ 5m from floor for cleaning purpose	
	Horizontal set up	

It was found from survey of various weather stations that the location should be for away at least eight times of the building height, or other hurdles which situated near the weather station. The location should have proper floor area which should be covered with grass and cutting of this is required time to time. One more prime thing should keep in mind that weather station should be away from heat exhaust area of any industrial or roof tops, steep slops, agricultural land shaded place, snow fall area etc.

5.1.2 Offset correction measurement

The data taken after a complete installation should match the official data taken from the nearest government weather station that only works professionally for it. For example, IGI Weather Station (Indira Gandhi International) were chosen as one of the stations because data can be easily from the airport website and our data can be verified accordingly.

Set up is installed according to the WMO standard which is mentioned in table 5.1. In fig. 5.1 depicts the wind direction sensor installation of IGI Airport.

Compared to where our weather has been configured, the IGI airport is less dense in population and forest, so there are slight data differences both in terms of location. We have compared the data to IGI Airport data only for an idea that we are taking proper decision to start measurement and we get that a positive indication found because the differences in both was in a limit.

Fig. 5.1 Wind speed and Direction sensor installation at Airport

5.1.3 Sample Timing

It is prime requirement to choose a proper timing for this evaluation with the consideration of the dynamic nature of solar radiation. Sample timing of weather station depend on solar insolation. In present study the minutes and hour data compared at various air masses.

The sampling needs to be done rapidly to avoid the data lost. This sampling timing should be very rapid in cloudy weather and maybe slow in the shining weather condition.

To begin with, we need to focus on one-day Ct clearance over the entire sampling period. It is the ratio between the current solar insulation G and the maximum possible insulation G0 (when there is no disturbance in the atmosphere)

$$C_t = \frac{G}{G_0} \tag{5.1}$$

As we know that the sensor has placed horizontal the elevation angle α is also came into picture. G0 calculated using external radiation H0 is 1400 W/m2 for a positive angle, which can be expressed as

$$G_0 = sin(\alpha) * \ k_0 \tag{5.2}$$

Elevation angle can be found in different time slot, and it changes location to location

Next step to find frequency of Ct for different time slices from 0 to 1 in xi (Ct). where n is the quantity and i is the frequency interval is Xi and X0

$$X_i = \sum_{i=0}^{i} x_i(C_t)(0 \leq i \leq n) \tag{5.3}$$

Then next plot is done at a clearance index ($f_i(c_t)$) after dividing the interval X_n

$$f_i c_t = \frac{X_i}{X_n} (0 \leq i \leq n) \tag{5.4}$$

A rapid sampling is done at the binging, which indicate a cloudy situation or sky is not clear

5.1.4 Wind Evaluation

Once the sampling rate is decided and measurements have been made, wind direction and speed must be evaluated. In this section, we will evaluate the relevant points.

5.1.4.1 Wind direction

To fully understand the wind direction, the direction data is divided into 16 directions, each of the 23^0.

To get a wind diagram a collective data of direction frequency is needed, which then divided by total amount of valid direction for finding the relative value. If the setup is correct in position and installed properly then it will give similar direction as nearby weather station which is situated at IGI Airport.

5.1.4.2 Wind Speed

Wind speed analysis was performed using Weibull and Rayleigh distribution. From this we have the form factor k and the scale factor c, which explain the details of the wind at a particular location. Small value of c depicts the low speed of wind and higher value describe the higher velocity, where G factor describe the degree of stillness of the wind. The Weibull-distribution describe by

$$t_{weibull}(v) = \frac{G}{c} (\frac{v}{c})^{k-1}. e^{-(\frac{v^k}{c})} \tag{5.5}$$

Calculation of the coefficients k and c will be calculated using mean wind speed $\bar{v}$ and standard deviation σ.

$$\bar{v} = \frac{1}{n}(\sum_{i=1}^{n} v_i) \tag{5.6}$$

$$\sigma = [\frac{1}{n-1}(\sum_{i=1}^{n}(v_i - \bar{v})2)]^{\frac{1}{2}} \tag{5.7}$$

$$k = (\frac{\sigma}{\bar{v}}^{-1.086}) \tag{5.8}$$

$$c = [\frac{1}{n}\left(\sum_{i=1}^{n} v_i^k\right)] \tag{5.9}$$

Taking a shape factor of 3 the Rayleigh distribution curve applied Weibull equation.

5.1.5 Solar Evaluation

To get the amount which reached the ground can be calculated by this solar evaluation. This solar isolation converted into the solar energy in the weather station to get a measurement, which depends on sampling time as well averaging of data. One month data is required to get a clear understanding.

$$H_{month} = (\sum_{i=1}^{n} I_i).12.678[\frac{Wh}{m^2}] \tag{5.10}$$

Solar irradiation data are found from satellite-based system which provide its data to the Centre of Excellence for renewable energy at New Delhi.

Data according to ground base is available from weather station at IGI Airport New Delhi.

5.2 Installation of weather station

5.2.1 Observation to the locations

Keep in mind the obstacles and limitations in order to perfect the installation location. Proper visual inspection allows visualization to decide on location. All the set up was installed at the roof to avoid the shading on the pyrometer and to avoid the damage of anemometer as well as wind vane. This entire situation would not recommend installing it at the ground. The location was chosen at the top of the building of canter of excellence for renewable energy with a proper permission by the inspection of concern authority. All places are in the range of radio wavelength.

Table 5.2 Advantages and Disadvantages of selected locations

Sr No	Location View	Description
1		**At the top of CoE in South-East** Direction: Height: 25 m Advantage: (i)Very less distance to receiver ii) direct sunlight Disadvantage: (i) Interference due to wind speed from north (ii) Difficult to maintain location
2		**At the Wall of East side** Height: 30 m Advantage: (i) direct sunlight (ii) easier maintenance (iii) Adequate electricity supply Disadvantage: (i) Wind disturbance

3		**In the Lawn area** Height: 20m Advantage: (i) No wind disturbance (ii) easier maintenance (iii) Adequate electricity supply Disadvantage (i) Shadow of roof in the direct sunlight
4		At The top most height of Building Height: 35m Advantage: (i) direct sunlight (ii)adequate accessibility (iii) No wind disturbance Disadvantage: (i) No lighting protection
5		**Terrace area of buiding** Height: 15m Advantage: (i) adequate accessibility (ii) adequate lighting (iii) Direct sunlight Disadvantage: (i) Wind Shadow from adjacent buiding (ii) Shadow to sunlight at the evening time

Finally the location 4 has been selected for the installation of own weather station due to its advantages which is more realistic and suitable for the investigation purpose. There was also a system for the solar energy has been installed which is having camera security which is also cover our setup.

5.2.3 Result

Table 5.3 contains the experimental setup specification for all sensors for maintaining the standard.

Table 5.3 Meteorological Specification

	Elevation above the floor	Specification	Fulfilled
Wind	2.25 m	AASC WMO EAP	NOK NOK NOK
Temperature and Relative humidity	1.75m	AASC WMO EAP	OK OK NOK
Rain	1.75m	AASC WMO EAP	NOK OK OK
Solar Radiation	• Planer setup • Without object ≥ 6^0 • ≤ 4 m above the floor for maintenance		OK

5.3 Measurements:

5.3.1 Temperature, Barometer Pressure and Relative humidity measurement

In this section, we found that changing various parameters in the configuration follows the trend of changing the same parameters at IGI Airport.

Fig. 5.4 depicts the temperature variation at both the places and provides an idea that how the own setup temperature trend is close to data of IGI airport

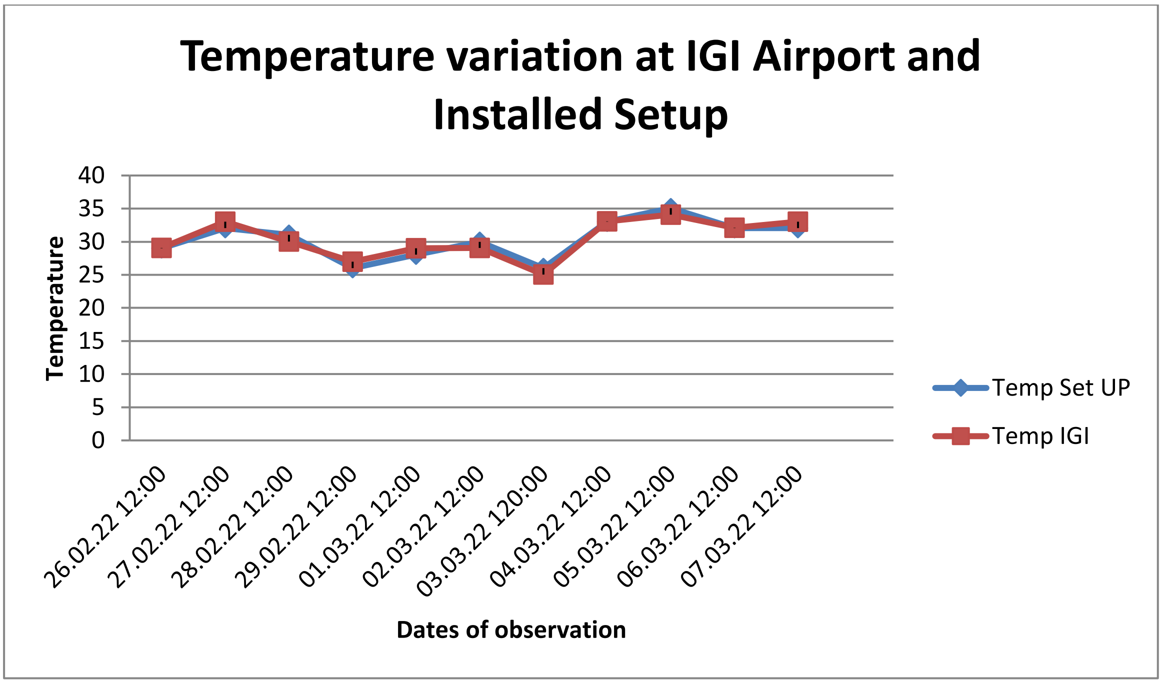


Fig 5.3 Temperature (^{0}C) variation at the CoE set up and IGI Airport

pressure variation is shown in Fig 5.4. it can be seen by the graph that setup installed at CoE has nearly 3 mbar more than the trend of IGI Airport

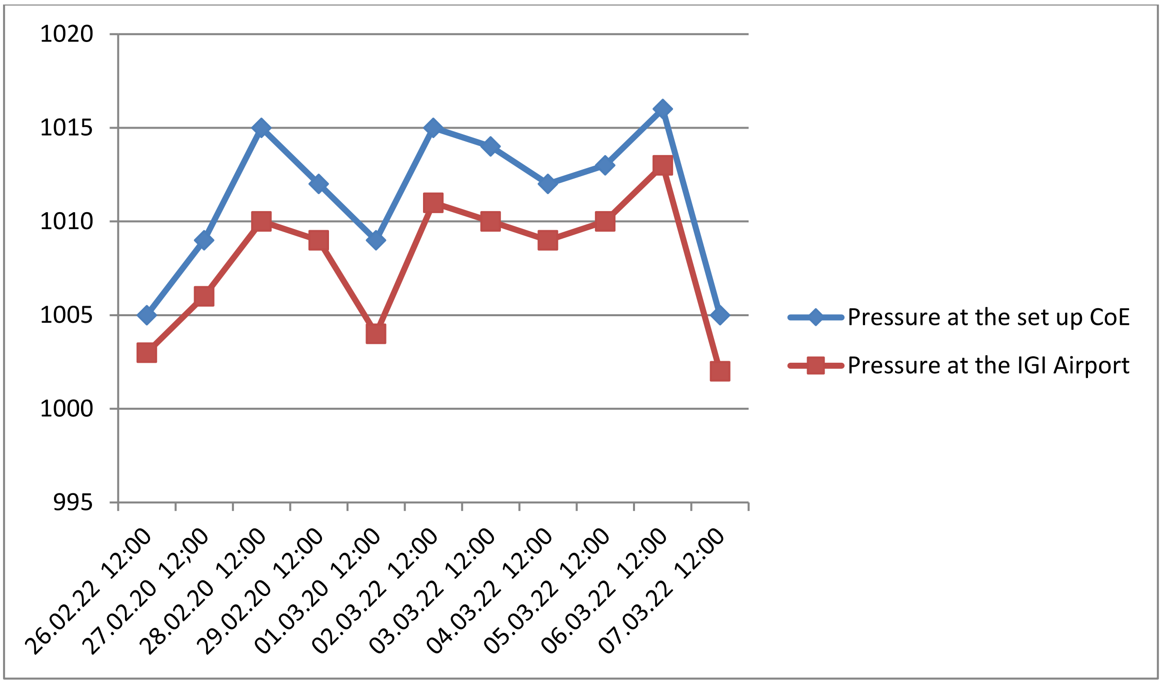


Fig 5.4 Pressure variation at the set up installed at CoE and at IGI Airport

Variation in Relative humidity is shown in Fig 5.5 to get a understanding the closeness of the this data at the installed set up and at IGI Airport

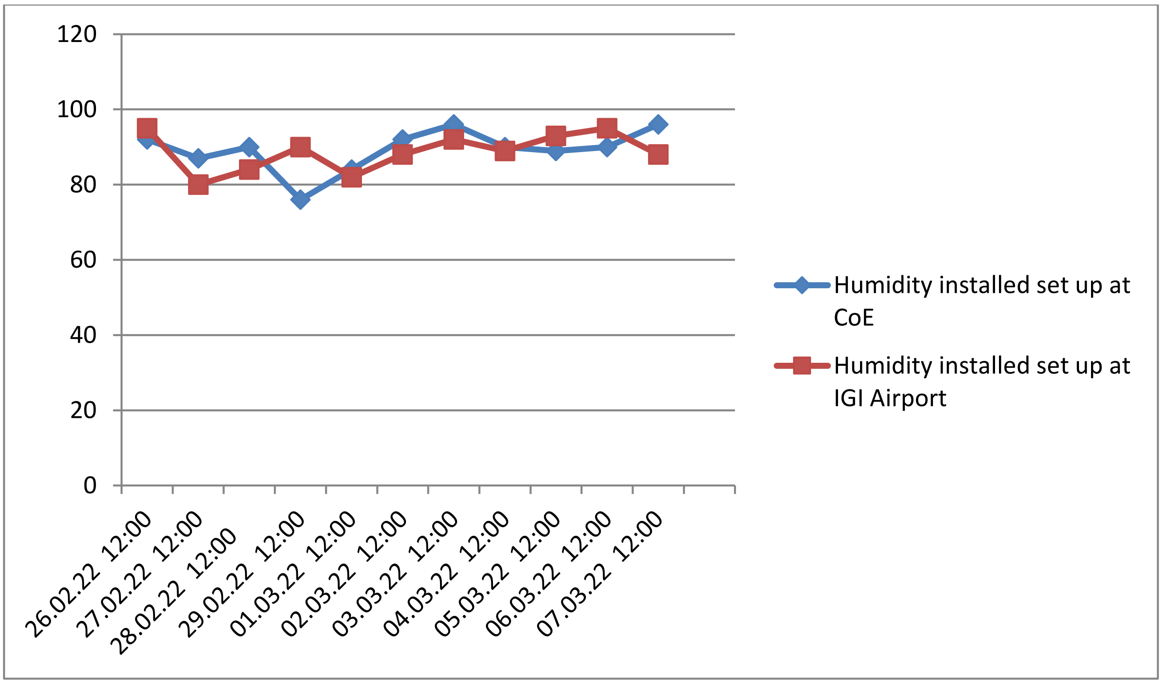


Fig 5.5 Variation in Relative humidity at the installed setup at buillding and at the IGI Airport

To get a clear understanding the average deviation has been calculated from the graphs which have shown above. Table 5.4 shows the deviation in various parameters at the installed setup.

Table 5.4 Deviation in Temperature, Pressure and Relative humidity at CoE

	Deviation
Temperature	0.4 ^{0}C
Pressure	1.9 mbar
Humidity	3.9 %

From this we can say that the installed weather station shows correct values, which indicates that the investigation can be start from this weather station. There is slight difference in data of both locations on same time that may be due to resolution of instruments and due to different environmental conditions.

5.4 Solar Radiation Investigation

The measurement was taken from February 27, 2022, to March 7, 2022. Data was taken from 11:55 am to 12:05 pm. and take the average, which is considered a perfect way to investigate.

Fig 5.7 depicts the variation in solar insulation for 1 minute, 10 minute and 1 hour for two different days, the days are chosen according to sun light availability first graph shows sunny day and second one is shows cloudy.

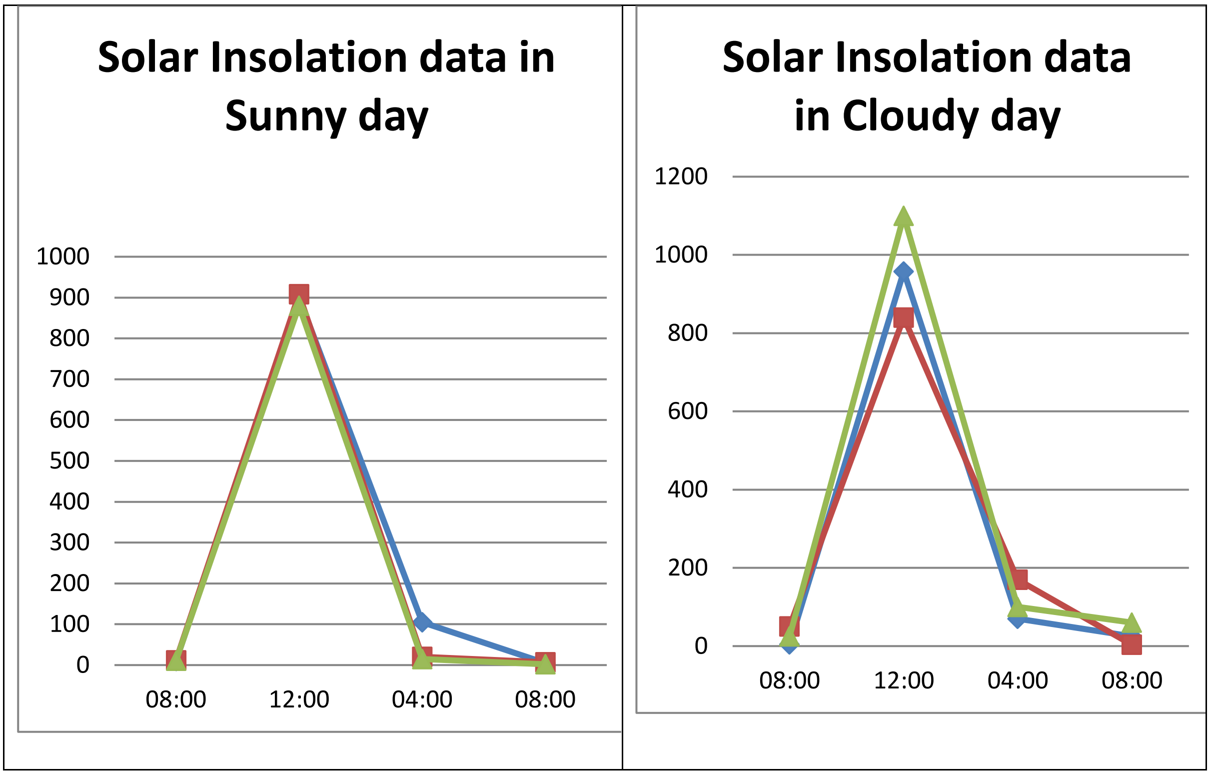


Fig 5.6 Sampling for 1 minute(Blue color), 10 minute(Red color) and for 1 hr (Graycolor) in sunny day and in cloudy day

5.5 Evaluation of wind data

For sampling, a total of 50,685 values were received over 2 minutes from February 2022 to March 2022. In the next section, we looked at changes in wind direction and wind speed for estimation purposes. This study is conducted to discuss the consequences of the measured values.

5.5.1 Analysis of wind speed

Weibull curve is used for analysis which is earlier discussed. Calculations for Weibull factors done with the help of equations which has earlier mentioned in the section 5.1.4.2. The findings are shown in table 5.5

Table 5.5 Average wind speed, standard deviation, shape factor and scale parameter in March 2022

	Average Wind speed $\overline{v}$	Standard Deviation σ	Shape Factor K	Scale Factor c
At Installed Weather station	1.48 m/s	1.32m/s	1.30	1.71 m/s

For the investigation of wind speed the process will be same as the done in the wind direction calculation. Fig. 5.8 represent the magnitudes with a bar diagram, it is found from this chart the maximum time the speed is 1-1.2 m/s. As per earlier discussion it was found that 40% time the wind in still condition or below 0.1 m/s. maximum value of wind speed takes place 10.5 m/s in March 2022.

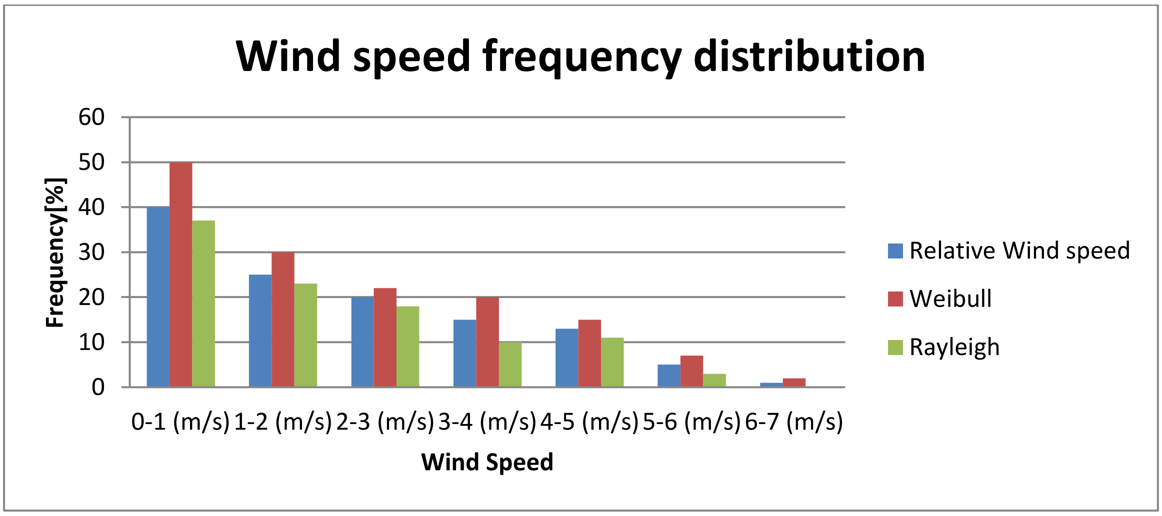


Fig. 5.8 Wind speed frequency, Weibull and Rayleigh observation for February 2022 and March 2022

5.5.3 Discussion in the aspect of wind speed and wind direction

There is a meteorological system at IGI Airport which maintains the wind data monthly with considering wind speed and wind direction. The available data shows that the record has been maintained from 26 Feb 2022 to till the date 7th March 2022. The investigation of data has been revealed that wind flow mainly North-West direction. The distance between IGI airport and the location where own weather station is installed is 9.7KM.

The wind direction at the installed weather station and the IGI Airport shows almost same pattern. There is slight difference in wind speed which may be due to technique used at the airport and the installed weather station.

Another reason may be the height of pole at the airport which is more than that of own set up weather station. At the installed set up of weather station at CoE the effect of ground obstacle is considered.

Having an average wind speed 2.01 m/s the CoE where own set up has been installed in not a windy location. Below mentioned table 5.6 depicts magnitude for the evaluation of wind energy potential.

Table 5.6 Average wind speed, standard deviation, shape factor and scale parameter in February 2022 and March 2022

	Average Wind speed $\bar{v}$	**Standard deviation σ**	**Shape factor k**	**Scale factor c**
IGI Airport	2.67 m/s	0.75 m/s	3.67	2.87 m/s
location of installed set up	2.01 m/s	1.85 m/s	1.97	1.86m/s

It can be seen that the average wind speed as well shape factor and scale factor at IGI Airport having large value than that of location of own installed weather station, it may be due to the outer space of airport from the city as well the open area are available at airport where a large area are restricted for any construction.

5.6 Solar evaluation for February 2022 and March 2022

5.6.1 Observation

The February and March heatstroke survey was conducted. For comparison, Figure 5.9 shows the distribution of two months. It can be seen that March receives more sunshine than February.

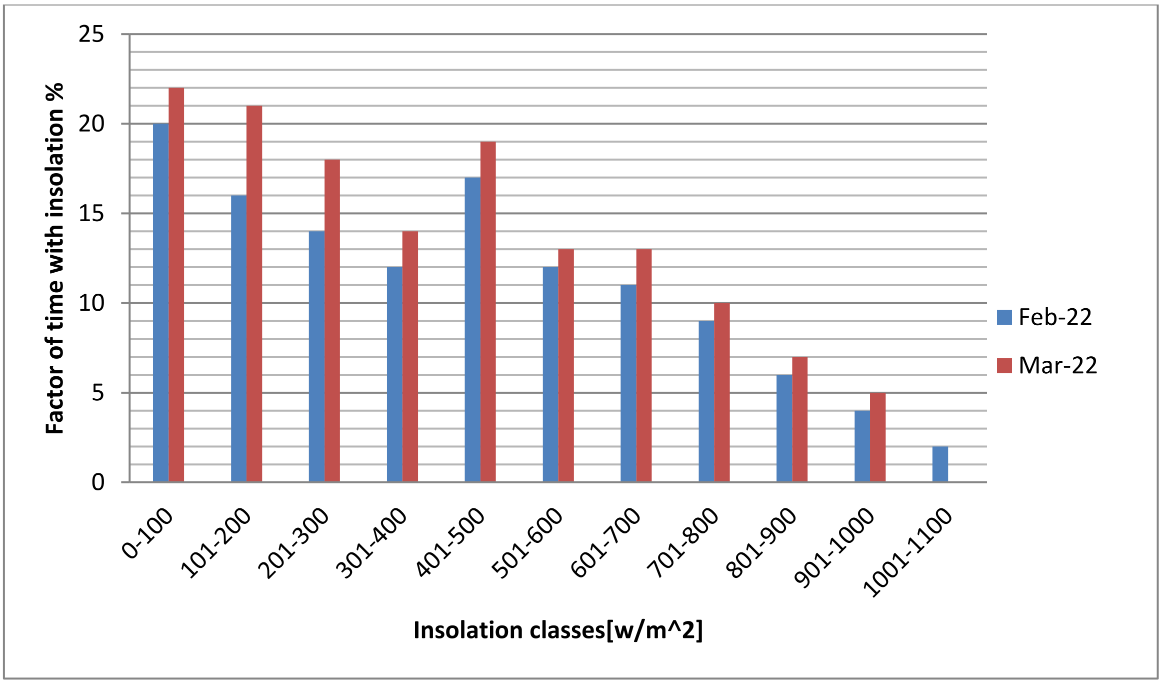


Fig.5.9 frequency of insolation in February 2022 March 2022

Collective energy for February and March month from the CoE weather station is 105.8 kWh/m^{2}. A comparison is made in daily and monthly average values measured with the help of satellite as well as ground base measurement which is presented in table 5.7.

Table 5.7 Solar insolation data for IGI Airport in February 2022 month measured by different mechanism

	Monthly kWh/m^2	**Average Daily kWh/m^2**
CoE Weather station	**112.7**	**4.02**
METER Weather Station Data, February and March	105.6	3.85
NASA-SSE Satellite	145.8	4.32
SolarGIS satellite	159.7	5.85

The value of daily average for CoE in February 2022 was 4.02 h/day, For February and March the value of solar insolation was 152kWh/m^2. The measurement is analysed with the same sources.

Table 5.8 Solar insolation data for IGI Airport in March 2022 month measured by different mechanism

	Monthly kWh/m^2	**Average Daily kWh/m^2**
Weather station	142.7	5.04
METER Weather Station Data, February and March	136.6	4.37
NASA-SSE Satellite	167.8	5.82
SolarGIS satellite	185.7	6.85

The value of daily average in March 2022 was 5.03 h/day, for and March.

The value of solar insolation is representing for February and March month in above mentioned tables. It can be observed that a deviation of 26%, 32% and 9% is seen METER, NASA-SSE, Solar GIS respectively for February month. This deviation is 16%, 20% and 8% is seen METER, NASA-SSE, Solar GIS respectively for March month.

5.6.2 Discussion in the aspect of solar insolation

Fig 5.9 shows the frequency variation for February and March month, it can be finding that the amount of isolation is higher in the March month. The reason may be due to start of sunny days, which causes increase of incidence. From observation it can be found that the maximum value of insolation occurs till 1000 to 1100 in the March month, a prime reason behind this that some time rain takes place in this season which clear the surrounding and provide a hurdle free surrounding.

From the various literatures survey, it was concluded that there in less deviation in the values of satellite based measurement and ground base measurement in the time when there is clear sky and fully overcast days. in the ground based data we can find a record for only a particular place but in the same time satellite gives a record of a region. We have mentioned about the error which occur due to the cloud or fog.

The mechanism followed by NASA-SSE uses PV simulation operator PVSyst. A small deviation from the own installed weather setup can be seen due to its large area resolution which reduces accuracy in the planer area.

Reason behind the larger deviation may be due to its location in New Delhi, large number of industries and a dense population who uses various appliances affects the aerosols of the air.

Solar evaluation is not very accurate because of it is found by derivations of satellite and ground base data. For a precise measurement the reading should be taken for a long duration nearly one year.

At the time of installation all the restriction by meteorological standard can't be avoided, due to limitation of cost and available of less time. To follow a standard, we should do some steps like heating above roof should be avoided, to be avoiding the superheated air. The tendency of warm air to stick at the roof surface when there is no wind is flow. To decrease the temperature derivations forced ventilation is required, or a grassland roof is also reducing the temperature derivations.

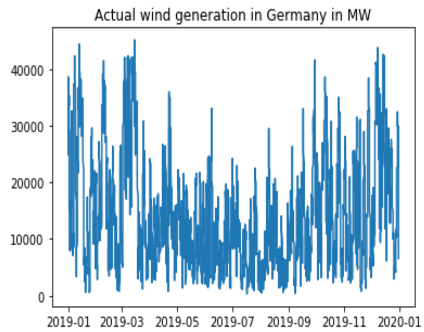
Now we shall discuss the second part of our experimental work to predict the solar energy by solar panel based on weather parameters.

5.7 Prediction of wind and solar generation (in python language):

First, we read the csv file containing the renewable energy production data relative to Germany. For that, we read the column containing the timestamp (whose column name starts with 'utc') and the columns containing German data (sourse : https://data.open-power-system-data.org). Following python code, we have analysed the wind energy and solar energy so that we can compare these curves based on the experimental curves.

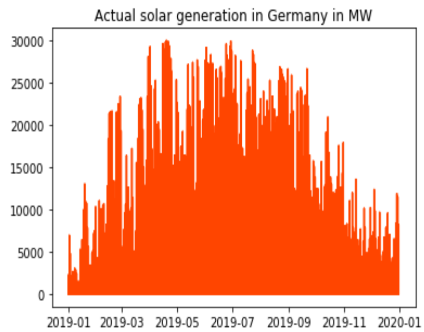
In [24]:

```
# create plot
plt.plot(production.index.date, production['DE_wind_generation_actual'])
plt.title('Actual wind generation in Germany in MW')
plt.savefig("C:/Users/asus/Desktop/kartikey/fig/wind.png", dpi=200)
```



In [27]:

```
plt.plot(production.index.date, production['DE_solar_generation_actual'], c='OrangeRed')
plt.title('Actual solar generation in Germany in MW')
# save plot
plt.savefig("C:/Users/asus/Desktop/kartikey/fig/solar.png", dpi=200)
```



5.7.1 Weather data

We have taken another dataset from the same repository as given above which contains weather information for Germany. We have used python for reading different weather variables like wind speed, radiation, and temperature. Following python code output is representing the data set for year 2016. We have chosen 2016 because it does not have any null value in the data.

```
In [16]:  1  weather.loc[weather.index == '2016-01-01 00:00:00', :]
```

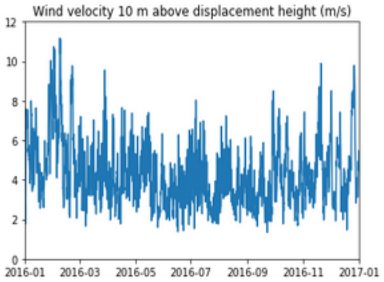
Out[16]:

timestamp	cumulated hours	lat	lon	v1	v2	v_50m	h1	h2	z0	SWTDN	SWGDN	T	rho	p
2016-01-01	0	47.5	5.625	0.81	1.88	3.36	2	10	0.052526	0.0	0.0	277.350159	1.236413	99282.710938
2016-01-01	0	47.5	6.250	0.85	1.77	3.69	2	10	0.163823	0.0	0.0	277.609924	1.226037	98194.710938
2016-01-01	0	47.5	6.875	0.94	1.94	3.79	3	11	0.286626	0.0	0.0	276.850159	1.205101	96186.710938
2016-01-01	0	47.5	7.500	0.84	1.68	2.82	2	10	0.109472	0.0	0.0	276.414612	1.200341	95874.710938
2016-01-01	0	47.5	8.125	0.74	1.56	2.51	2	10	0.066503	0.0	0.0	276.039612	1.202233	96050.710938
2016-01-01	0	47.5	8.750	0.76	1.49	2.37	2	10	0.051061	0.0	0.0	275.898987	1.201012	95842.710938
2016-01-01	0	47.5	9.375	0.75	1.27	1.83	2	10	0.082921	0.0	0.0	275.578674	1.181908	94178.710938
2016-01-01	0	47.5	10.000	0.88	1.59	2.32	4	12	0.398931	0.0	0.0	274.123596	1.146264	90998.710938
2016-01-01	0	47.5	10.625	0.81	1.38	1.93	6	14	0.813970	0.0	0.0	273.670471	1.117516	88518.710938
2016-01-01	0	47.5	11.250	0.56	0.86	1.09	10	18	1.666021	0.0	0.0	274.074768	1.118920	88486.710938
2016-01-01	0	47.5	11.875	0.33	0.47	0.59	11	19	1.786626	0.0	0.0	274.301331	1.123864	88834.710938
2016-01-01	0	47.5	12.500	0.58	0.98	1.32	11	19	1.786138	0.0	0.0	272.826721	1.114037	87786.710938
2016-01-01	0	47.5	13.125	0.26	0.90	1.44	10	18	1.750005	0.0	0.0	272.853088	1.122155	88246.710938
2016-01-01	0	47.5	13.750	0.08	0.97	2.32	10	18	1.767095	0.0	0.0	271.089905	1.115258	87398.710938
2016-01-01	0	47.5	14.375	0.06	1.10	3.07	10	18	1.743657	0.0	0.0	271.062561	1.127038	88282.710938
2016-01-01	0	47.5	15.000	0.12	1.39	3.48	10	18	1.716802	0.0	0.0	271.574768	1.149498	90066.710938
2016-01-01	0	48.0	5.625	1.90	2.90	4.12	2	10	0.052312	0.0	0.0	276.928284	1.234093	98314.710938
2016-01-01	0	48.0	6.250	0.65	1.67	3.36	4	12	0.424810	0.0	0.0	277.461487	1.224938	98010.710938
2016-01-01	0	48.0	6.875	0.38	1.68	3.16	7	15	1.153814	0.0	0.0	277.238831	1.210351	96674.710938
2016-01-01	0	48.0	7.500	0.88	1.79	2.89	3	11	0.238103	0.0	0.0	276.432190	1.224205	98114.710938
2016-01-01	0	48.0	8.125	0.31	1.19	2.32	9	17	1.438970	0.0	0.0	275.115784	1.185936	94314.710938
2016-01-01	0	48.0	8.750	0.74	1.49	3.19	2	10	0.100133	0.0	0.0	275.313049	1.188744	94274.710938
2016-01-01	0	48.0	9.375	0.48	0.73	1.07	2	10	0.067174	0.0	0.0	275.361877	1.204918	95594.710938

Following 4 plots is representing the variation of metrological variables over the period of year 2016.

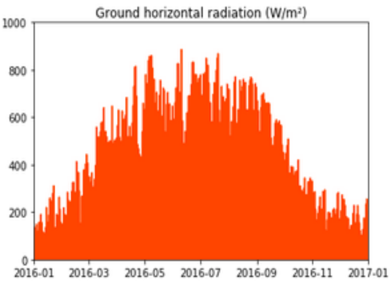
In [20]:

```
# create plot
plt.plot(weather_by_day.index, weather_by_day['v2'])
plt.title('Wind velocity 10 m above displacement height (m/s)')
plt.xlim(pd.Timestamp('2016-01-01'), pd.Timestamp('2017-01-01'))
plt.ylim(0, 12)

# save plot
plt.savefig("figs/v1.png", dpi=200)
```



In [21]:

```
# create plot
plt.plot(weather_by_day.index, weather_by_day['SWGDN'], c='OrangeRed')
plt.title('Ground horizontal radiation (W/m²)')
plt.xlim(pd.Timestamp('2016-01-01'), pd.Timestamp('2017-01-01'))
plt.ylim(0, 1000)

# save plot
plt.savefig("figs/radiation.png", dpi=200)
```

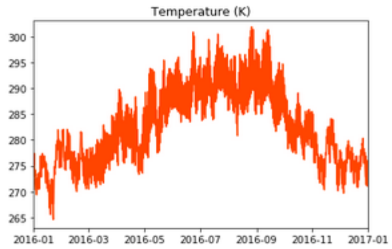


As with the wind generation, we see that the wind velocity does not follow a specific pattern, although it was larger in February, November and December.

Following plot is showing as temperature is maximum during the summers.

In [22]:

```
# create plot
plt.plot(weather_by_day.index, weather_by_day['T'], c='OrangeRed')
plt.title('Temperature (K)')
plt.xlim(pd.Timestamp('2016-01-01'), pd.Timestamp('2017-01-01'))
plt.ylim(263, 303)

# save plot
plt.savefig("figs/temperature_K.png", dpi=200)
```



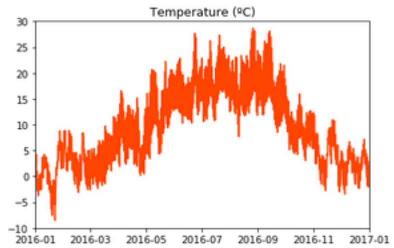
Let's use the more common Celsius units for the temperature.

In [23]:

```
weather_by_day['T (C)'] = weather_by_day['T'] - 273.15
```

In [24]:

```
# create plot
plt.plot(weather_by_day.index, weather_by_day['T (C)'], c='OrangeRed')
plt.title('Temperature (ºC)')
plt.xlim(pd.Timestamp('2016-01-01'), pd.Timestamp('2017-01-01'))
plt.ylim(-10, 30)

# save plot
plt.savefig("figs/temperature_C.png", dpi=200)
```



5.7.2 Solar generation

The above 3 graphs are showing collinear behavior with respect to temperature; therefore, we can apply regression method in above cases for the prediction of solar energy.

The performance can be measured by the term R^2 which is called as coefficient of determination. A value near 1 will represent good prediction near the true values.

$$R^2 = 1 - \frac{\sum_i (y_i - f(\mathbf{x}_i))^2}{\sum_i (y_i - \bar{y})^2}$$

In the following python code we have chosen features SWTDN (total top of the atmospheric horizontal radiation), SWGDN (total ground horizontal radiation) and T(temperature) to train.

In [38]:
```
X_solar = combined[['SWTDN', 'SWGDN', 'T']]
y_solar = combined['DE_solar_generation_actual']
```

Then, we implement a 5-fold CV procedure:

In [39]:
```
scores_solar = cross_val_score(lr, X_solar, y_solar, cv=5)
print(scores_solar, "\naverage =", np.mean(scores_solar))
```

```
[0.8901974  0.95027431 0.95982151 0.95090201 0.8715077 ]
average = 0.9245405855731855
```

The first line of output is showing 5 different value of R^2, and the second line is representing their average value. We can see that average value is 0.924540 which is very near to 1 and thus it represents a good prediction to the true value.

CHAPTER 6

Conclusion and Future scope

In first part of our experiment, we have setup 5 observatory stations to record the data using sensors. The data of Temperature, relative humidity and wind speed was compared with the data on official website of IGI airport. It was found that the Temperature variation on setup and temperature variation on IGI airport was very close. Similarly, the data of relative humidity and wind speed at IGI Airport and setup was also similar. By this assessment we can find that to install a solar panel for energy conservation the metrological conditions like Temperature, relative humidity, and wind speed play very important role.

If PV installations are to be made in the future, some guidelines in this study should be followed. Meteorological stations can make weather forecasts to calculate energy yields. The data recorded by the meteorological station and PV system can be used for future research work. Apart from the statistical data used in this study, IGI airport data should also be used for future work comparison purposes. The previously proposed improvements should also apply to future work. Davis guarantees a 2% variation in solar rating for one year and provides guidance for further calibration.

The ongoing efforts of the Renewable Energy Excellence Center (CoE) to study in the field of renewable energy by providing the best possible services to researchers in the field of renewable energy will make India the energy sector. Has made a significant contribution to making it an emerging market. make. We gather real-world experience when planning future PV systems at meteorological stations. The measurements at my meteorological station are still functioning and there are no problems with the operation of the meteorological station. You can get some data for future observations. This environment is intriguing to various researchers working in this field.

We have also done prediction of solar energy based on temperature and radiance parameters we have taken data sets from repository https://data.open-power-system-data.org. First we have trained the system by the actual data of solar energy generation for the year 2016 then we have analyzed variation of different metrological parameters over the period of one year i.e 2016. We have found that temperature and radiance are showing collinear properties with respect to time and therefore they can be used for regression analysis of machine learning. For output prediction a term coefficient of determination(R^2) has been used its value near 1 is showing a true prediction of solar energy based on only two parameters temperature and radiance.

Future Scope

Modelling of photovoltaic systems could be a future work in this field of research. The main disadvantage is that there is a significant investment during installation. To overcome this, thin-film technology can be used at a reasonable cost. The accessibility area above the CPU building has an 8.5 kW peak power plant that can be installed at 8.95 MWh per year. Changes in the observable base in crystalline descriptions for hot climates are often affected by the temperature coefficient. This system used the base surface of the top of the building. To maximize the efficiency of available space, crystalline technology that takes up very little working space should be used. Our main concern is the analysis of a scientific approach, as our motive is not the concern for best performance.

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IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Assessment of Solar Energy Based on Various Meteorological Conditions in the Indian Climate

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ABSTRACT

India has the largest DNI rating network, with 51 weather stations pre-programmed with the highest commercial quality solar settings. Some stations are performing well, while others are in need of intensive improvement. We focus on specific difficulties and misconceptions observed in the operation of various solar stations in the field. Analysing Indian solar sites to make a weather measurement methodology is the prime motivation of this study. Weather stations can observe all common phenomena occurring under weather conditions and solar isolation conditions. The monitoring of various sites is done for a period of time to get a detailed analysis of the impact of changes in weather conditioning on the solar energy.

Significant differences in insolation were found when comparing satellite and ground-based measurements. At some sites, it was found that the average deviation of solar isolation for a period of 15 days was 40% from the satellite base observation but for the same period of time this deviation is less than 12% when measured from the ground base. The data on wind speed and direction also has been collected from the local weather station. All roofs are equipped with solar panels. The monthly and annual output of the solar system was modelled using various simulation processes. Using a variety of state-of-the-art technologies, a solar power plant with a peak power of 8.3 kW can produce 9.03 MWh per year, and with the addition of thin-film technology it can reach 9.67 MWh per year. It can be concluded that the use of environmentally friendly technologies can lead to low cost development. It has been concluded that sometimes multiple implementations are needed, such as simulating solar power performance. In this study, we also describe a set of measures for the procedure to bridge the gap in insolation installations.

Keywords: Solar Power Plant, PV-system, Weather Link, **Sensor Interface Module**

INTRODUCTION

India has proposed a separate and independent ministry for opportunity power sources. It is roughly calculated that the energy requirement will grow27% from 2022 to 2045. India also emits a huge amount

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