Solar Resource Assessment and Potential in Indian Context

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Abstract. The demand for electricity is increasing day by day causing environmental problems due to the widespread burning of fossil fuels. Therefore, research has been promoted in solar energy to mitigate environmental pollution. The land of India receives a good amount of solar energy. This paper describes the assessment of solar radiation resources in India. All solar resource stations have advance measuring instruments of the same type to collect, store and send radiation and meterological parameters at central station National Institute of Wind Energy (NIWE) Chennai. One year solar data from January to December 2015 of DCRUST, Murthal center is assessed, which assist solar project developers for feasibility analysis and development of new solar projects in this area. Moreover, state-wise solar potential and installed capacity are also described. This study is significant for design, modeling and performance analysis of solar plants. In addition to this solar resources give impetus for the deployment of solar energy along with futuristic solar technologies in India.

Keywords: Solar resource, solar energy, radiation, solar potential.

1 Introduction

The role of energy is critical for industrial and socio-economic development of any country [1]. India's energy need, along with growing population is mainly lead by the conventional fuel based sources which are depleting day by day [2].

Being an emergent nation, India's entire installed capacity of power from diverse resources is 1.362 GW in 1947 to 344.002 GW at the end of the financial year, 2018 [3]. India’s power-producing capacity is mainly commanded by coal since independence [4]. The conventional sources affect the environment as well as the health of human beings. These problems will make unsustainable situations and create irreversible threat towards human societies [5]. India’s strategy towards sustainable renewable energy is an important pillar to fulfill the ever-rising demand for electricity while addressing energy security, climate change, greenhouse gas emissions, and water shortage objectives. Moreover, Renewable energy emerged as a sustainable alternative source of energy and offer an accessible solution to the growing challenges [6]. In addition to this deployment of reliable, affordable and modern renewable energy technologies offer an excellent opportunity as a green energy solutions for mankind.

In order to meet up electric demand of India, sustainable renewable sources along with moderen energy technologies will provide a prominent solution for the overall development of India. During the Paris agreement, the Government of India committed to raising the percentage share of sustainable renewable energy from 30 % in 2015 to 40 % by 2030 [7]. This incorporates an ambitious target of implementing 175 GW from renewable sources by 2022, and from this 100 GW is only planned through solar energy [8]. To fulfill the increasing energy demand of India in a sustainable way, the emphasis is being given for the development and dissemination of solar energy. Moreover, in India solar energy plays a critical role in future energy mix [8]. Such an initiative requires the identification of suitable areas for development and dissemination of solar electric power. A detailed potential evaluation for the whole nation and identification of niche area shall be of great help for the researchers, policymakers, and solar developers.

1.1 Current Power Scenario in India

The power sector is the growth engine for economic, industrial and societal development of any country. Access of affordable, quality and sustainable power is the basic need of Indian communities. It is evaluated that the consumption of energy in India may increase by 132 % where the electricity demand may increase three times by 2035 [9]. Fig. 1 illustrates the source-wise all India installed capacity of power as on 31st March 2019.

Being a developing nation, India’s overall installed capacity in terms of power from various sources is 1.362 GW in 1947 to 356.1 GW as on 31st March 2019 [3, 10]. The share of thermal power is 63.54 %, the contribution of renewable energy is 21.80 %, and hydropower holds 12.75 % while nuclear power share is 1.90 %. Moreover, a major source of power supply in India is from coal-based thermal power with 56.36 % share [10]. Therefore, coal act as a prime source of power since independence and also the main source of environmental pollution.

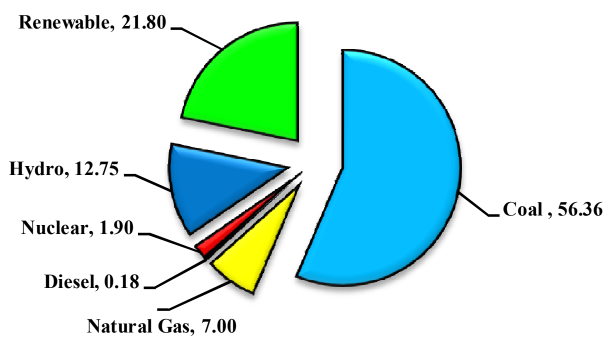

Fig. 1 Source-wise all India installed capacity of power in percentage (*Source* [10], p.1)

Now it is time to look ahead to augment the share of renewable power in the Indian power sector. The blend of renewable energy will meet the ever-growing demand for power without breaching environmental laws [11]. The solar energy plays a critical role to achieve the 100 GW ambitious targets of solar power in India by 2022 [8]. And this is the driving force towards to assess the solar radiation resources and solar potential. Therefore, solar energy has the immense potential to lead the Indian power sector in a sustainable manner. India's total installed capacity of sun-based power is 28.18 GW as on March 2019. Fig. 2 described the growth story of solar power in India [10, 3].

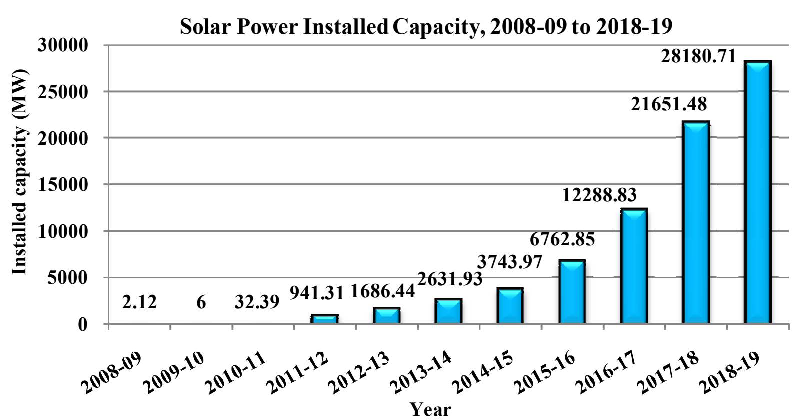

Fig. 2 Growth of solar power in India (*Source* [10],p.1, [3], p. 26])

The growth of solar power started at 2.12 GW in the year 2008-09 and observed the marvelous growth with 28.18 GW by the year 2018-19 [3, 7]. Moreover, for escalating solar energy utilization, the Indian government has implemented various policies and schemes in a different time frame.

1.2 Harnessing Solar Energy in India

Solar energy is abundant in nature and largely untapped resource which has the potential to resolve the ever-growing demand of power in a sustainable manner. Solar radiation emits from the sun at the rate of 3.8 X 10^{23} kW and out of this nearly 1.8 X 10^{14} kW is received on the earth [12]. Solar radiation can be harnessed in the form of heat and light. The dominant part of the radiation is lost in the form of reflection, absorption, and scattering by clouds. Though, solar energy is sufficient to fulfill the entire electricity demand of the world [13].

India has tremendous scope of harnessing solar energy to meet the overall demand of the electricity. India's demographic position as a tropical nation, having landmass of 2.9 million Km^2 with excellent solar irradiance has huge potential to harness solar energy. India is blessed with 250-300 sunshine days in a year, annual solar irradiance of 4-7 $kWh/m^2/day$ to generate 5000 trillion kWh of energy [14, 15].

The potential use of solar energy in India mainly depends upon the assessment of solar radiation resources and availability of land. Therefore, to harness the solar energy it is necessary to assess the solar radiation resources of the country which have a significant impact towards the design of the solar plant, solar resource forecasting, and solar technology selection. Moreover, based on the availability of land in the country, it also helps to assess the solar energy potential in the country. So to explore the potential use of solar energy, it is necessry to study the state of solar energy in Indian context.

2 State of the Solar Energy

The segment of solar power in India is increasing at a rapid rate with the goal of 100 GW solar power mission till 2022 [16]. Production of solar power is directly influenced by the amount of incident radiation at a specific site. The yield of this environmentally friendly power relies on the radiation quality, sunshine hour, ambient temperature and use of solar technology [17,18]. Therefore, precise, high quality, reliable and accessibility of solar radiation data and meteorological data is imperative for solar energy development [19].

Estimation of ground-based solar data needs precise measurements. Pyranometer a solar radiation measuring apparatus is utilized for DHI (Direct Horizontal Irradiance) and GHI (Global Horizontal Irradiance) while Pyrheliometer is utilized for DNI (Direct Normal Irradiance). The quality of solar data can be kept up at a specific level by removing uncertainty, operational mistakes and instrumental errors [20]. There are various forms of solar radiation data are available but for site-specific analysis, satellite-based solar data is used. The success story of any site-specific solar project requires at least one-year ground-based solar data [21]. In addition to this, the recognition of any solar project is profoundly dependent upon the measurement of solar resource quality and its appraisal [22].

Solar data of any region plays a critical role for assessing the solar potential and for selection of solar applications in that zone [23-25]. The knowledge of solar radiation evaluation is essential for solar system designing, modeling, simulation, and analysis as well as for solar appliances and development of futuristic solar technologies [26-28]. Evaluation of global solar radiation assumes an essential job for solar technologies and applications selection along with feasibility evaluation of solar project [29, 30]. Karakoti et al., (2012) [31] analyzed the diffused solar radiation data of 23 solar stations in India and suggested the empirical models which demonstrate the relationships with daylight hours, temperature and relative humidity. Kandasamy et al., (2013) [32] assessed the solar energy potential using PVSYST software in the Tamil Nadu state of India. Abubakar and Muthuchamy (2017) [33] assessed the solar power potential in three states i.e Tamil Nadu, Kerala, and Karnataka using Photovoltaic Geographical Information System (PVGIS). Moreno-Tejera et al., (2015) [34] explored the parameters and solar radiation data which influence the evaluation of solar power of the specific local site. Zafarani et al., (2018) [35] evaluated the utility of meteorological data for estimating solar power.

Few studies have been depicted about the potential estimation and solar radiation appraisal in the Indian context. Ramachandra et al., (2012) [36] assessed the solar power potential of Himachal Pradesh utilizing the satellite-driven GHI data collections. Schwandt et al., (2014) [37] examined the 51 Indian solar centers data of solar radiation. There are some gaps observed in solar radiation data because of instrumental errors, misalignment, failures of power supply, stations operational errors and maintenance problems, etc. Additionally, the technique of gap filling is depicted and further checked the quality of solar radiation data. Harinarayana and Kashyap (2014) [38] described the factors which affect the generation of sun-based energy in India and the total yearly energy production varies from 510,000 to 800,000 kW/acre of land. Gupta et al., (2017) [39] depicted the solar and wind asset appraisal process for India. Sharma et al., (2017) [40] analyzed the solar and climatologically parameters which have a significant effect to evaluate the solar energy potential. Moreover, authors also explored the solar potential based upon availability of wasteland of the country. Mahima et al., (2018) [41] studied the solar radiation pattern for a specific area which is imperative for the determination of solar applications based on their performance. Raghuwanshi and Arya (2019) [42] investigated the solar energy potential in the Indian context and promoted clean and green energy technologies to fight against environmental pollution.

It is very important to assess solar radiation precisely for the growth of clean and green energy in India. This requires quality and reliable solar database. Also, India still needs more solar resource centers for the solar database so as to fulfill the accurate assessment of solar based resources. This article summarizes solar centers network design, usage and quality affirmation of solar data. This investigation also incorporates the examination of one-year solar radiation parameters information of a specific station. In addition to this, present investigation contributes significant effect towards an assessment of solar potential, technological selection, forecasting of solar resources and solar based modeling of power plants in India as well as globally.

3 India’s Solar Radiation Resources

Deployment of solar energy in India and for designing solar power plant needs quality and reliable solar radiation data. Precise evaluation of ground-based solar data and other meteorological parameters are the basic essential elements for solar radiation resources assessment and potential estimations, which can accomplish the following objectives:

- Provides database for solar project developers, solar manufactures, solar researchers and policymakers.
- Support the development of analysis tools, solar technologies and predict solar resources.
- Facilitate meteorological research in the country.
- Support in potential estimations in India as well as at a particular area.

Solar radiation is the imperative parameter to appraise the potential and power yield of the solar plants; however, it doesn't reach on earth in a full amount. Some portion of the radiation is absorbed, some reflected and some dispersed because of complex interactions of the Earth's climate with the occurrence of solar radiation. So there is a need to think about the basic of radiation, which is used in solar powered conversion technologies [22]. Generation of electricity from solar technologies requires solar irradiance as input. The basic knowledge of solar irradiance as well as measuring instruments is essential to evaluate the solar data and further to evaluate the solar potential. There is a huge potential for solar energy in India. So the assessment of solar resource is very important to harvest environment-friendly solar power.

3.1 Network of Solar Radiation Resource

National Institute of Wind Energy (NIWE) under the aegis of Ministry of New and Renewable Energy (MNRE), Indian government started a pilot project in the year 2011 in phase manner of erection and commissioning of SRRA stations all over the India in technically collaboration from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ GmbH). In the first stage, 51 SRRA stations were established by NIWE in 11 states and 1 in Union Territory. While in the second stage, 60 SRRA stations in 28 states and 3 Union Territories alongside 4 Advanced Measurements Stations (AMS) were also set up by June 2014. NIWE has additionally commissioned 6 SRRA stations for Maharashtra Energy Development Agency (MEDA) in Maharashtra, under consultancy mode by May 2015 [43, 44]. So at present in India, a total of 121 SRRA stations was established by NIWE.

The network of Solar Radiation Resource Assessment (SRRA) stations in India is one of the most advanced setups for assessment and measurement of solar irradiance, processing and handling of data, quality assurance, modeling and development of solar atlas of the country. Moreover, data collection and assessment of meteorological parameters is also done by SRRA stations for the dissemination of solar power in the country [39], [43]. Fig. 3 illustrate the solar resource data flow in India.

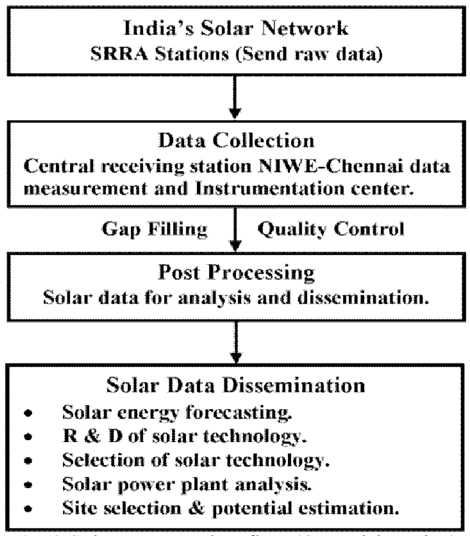

Fig. 3 Solar resource data flow (Own elaboration)

3.2 Instruments in Indian Solar Resource Stations

Radiation is an important factor for design, performance and site selection of solar plant. There are various ways and technologies for the measurement of solar irradiance. During measurements, there are other meteorological parameters such as ambient temperature, atmospheric pressure, wind speed, wind direction, relative humidity and precipitation which are very important to measure because these parameters affect solar irradiance. Fig. 4 illustrates the instruments installed at one of the SRRA stations in India.

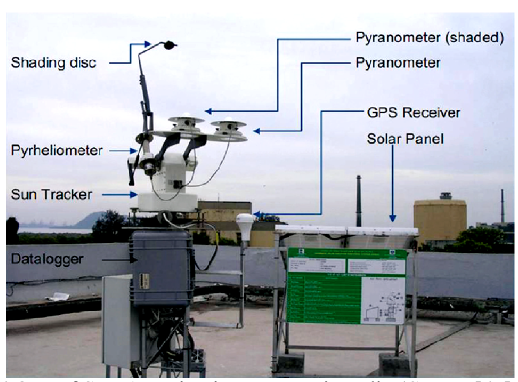

Fig. 4 One of SRRA station instruments in India (*Source* [45], p.3)

In India, all SRRA stations are identical in design and have the same model and quantity of instruments. Table 1 illustrates the instruments and sensors mounted in SRRA stations with their model and manufacturer details [46].

Table 1 Details of instruments used in SRRA station (*Source* [46], p. 3)

Instrument Types	Parameters Measured	Manufacturer-Model
1st Pyranometer	GHI (W/m^2)	Eppley Lab USA-PSP
2nd Pyranometer	DHI (W/m^2)	Eppley Lab USA-PSP
Pyrheliometer	DNI (W/m^2)	Eppley Lab USA-NIP
Solar Tracker	Mounted with shaded pyranometer & pyrheliometer	Geonica Spain- SMT-3
Temp. & Relative Humidity Sensor	Ambient Temp. (ºC), Humidity (%)	RM Young, USA-41382VC
Ultrasonic Wind Sensor	Wind speed (m/s), Wind direction (^{o})	RM Young, USA-85000
Rain Gauge	Rain accumulation (mm)	RM Young, USA-52203
Barometer	Atmospheric pressure (hPa)	RM Young, USA-61302L
Data Logger & Modem	Gathering data from instruments & send it to central station at CWET, Chennai.	Geonica, Spain
GPS	Synchronise sun tracker with sun movement.	Garmin, USA
GPRS	Transfer data through mobile sim-cards to central stations CWET, Chennai.	Garmin, USA
Solar PV Panel	Supply power for charging station batteries.	Moserbaer, India
External Batter	Electrical storage	Exide, India

To decrease the fossil fuel based power percentage, the solar-generated power will play a critical role in the Indian power sector. So the estimation of solar irradiance is essential to deploy the environmental friendly clean and green power in the country. The database of solar irradiance and meteorological parameters are measured at SRRA stations, after that send and stored at C-WET-Chennai (NIWE) central station.

3.3 Solar Data of Murthal Station

Solar energy availability is free and in great amount, due to its sustainable and environmentally friendly nature which has immense potential to fulfill the energy requirement and mitigate the greenhouse gas emissions. The Indian government has set up the world largest SRRA network. One such station is established in D.C.R.U.S.T, Murthal (Station ID-2389) in the year 2013. The latitude, longitude, and elevation of the station are 29^{o}1' 40.9" N, 77^{o}3' 28" E and 213m amsl respectively. In this study, we explore the solar irradiance data and other meteorological data of the year 2015 of D.C.R.U.S.T, Murthal station. Table 2 illustrates the average monthly values of solar irradiance and meteorological parameters of the year 2015.

Table 2. Average monthly values of solar irradiance and meteorological parameters of the year 2015 (*Source* SRRA Murthal Station-2389).

Month	GHI ($kWh/m^2/d$)	DNI ($kWh/m^2/d$)	DHI ($kWh/m^2/d$)	AT (˚C)	RH (%)	WS (m/s)	WD (˚)	PR (hpa)
January	2.4	1.4	1.7	11.4	88	2.3	299	989
February	3.9	2.9	2.0	17.1	37	2.7	327	986
March	4.9	3.7	2.3	20.2	15	3.0	293	985
April	5.7	3.5	3.0	26.8	44	3.0	84	980
May	5.2	2.6	3.3	32.7	42	2.8	270	975
June	6.0	2.6	3.8	30.1	52	2.9	265	972
July	4.9	1.6	3.6	29.8	25	2.8	125	971
August	4.6	1.3	3.3	29.0	34	2.2	240	974
September	5.2	1.9	3.7	28.8	87	2.6	299	978
October	4.4	1.8	3.1	26.0	68	2.1	312	983
November	2.9	1.5	1.9	21.0	65	1.9	324	986
December	2.1	0.4	1.8	14.8	83	2.0	291	989

4 Solar Energy Potential in India

The GOI has released various reforms to increase the solar energy mix in the Indian power sector so that to sustain the development of the country. The Indian government has implemented several policies, schemes, and projects, especially since the commencement of the Jawaharlal Nehru national solar mission (JNNSM). Due to the various reforms, prominent growth in the solar sector has been observed with an installed capacity of 2 MW in the 2008-09 to more than 28000 MW in 2018-19 [10]. Solar power is an emerging industry in the Indian power sector. The Indian government has given emphasis to expand its solar plans, targeting 100 GW addition of solar capacity by 2022 [8].

In India, the availability of solar energy is around 5000 trillion kWh/year. The ability of solar power production in India is about 0.20 kWh/m^2 [49, 50]. In terms of solar capacity, India stands on the tenth position in the world, but in the near future, India could be one of the highest generators of sun-based power. The present Indian government reforms were going in the right direction to bring solar revolution by 2022. Moreover, India could emerge as a world leader in solar market to achieve sustainable manufacturing of solar products along with economical energy. This can be achieved under the “Make in India” mission so that to decrease the rate of solar power [51]. The production of solar power is influenced by the various parameters such as radiation, climate, and geographic position and also has a significant effect on the solar potential estimation [40], [38]. The assessments of the potential exploration rely on the wasteland selected, solar irradiance and wind speed for solar thermal and solar photovoltaic power generation.

For setting up of utility-scale solar plants in India, there is plenty of wastelands available in the country. It is estimated that the 3% wasteland of the nation is sufficient to generate 748.98 GW of power by harnessing solar energy [8], [52]. Table 3 illustrated the state-wise estimated solar potential and solar installed capacity as on 31st March 2019 [53], [54]. It is also evaluated that approximately 46.7 million hectares of wasteland is accessible in India for solar energy [52]. Table 3 shows that the total estimated solar potential is 748.97 GW while so far India's total solar installed capacity as on 31.03.2019 is 28.181GW. It is observed that there is a huge gap exists between estimated solar potential and solar installed capacity so far. Therefore, there is a great opportunity to harness the solar energy and fulfill the entire demand for electricity of the nation.

Table 3. State-wise estimated solar potential and solar installed capacity as on 31.03.19 (*Source* [53], pp. 2-3, [54]).

Sr. No.	States/ UTs	Solar Potential (GW)	Solar Installed Capacity (GW)
1	Andhra Pradesh	38.44	3.085
2	Arunachal Pradesh	8.65	0.005
3	Assam	13.76	0.022
4	Bihar	11.2	0.142
5	Chhatisgarh	18.27	0.231
6	Delhi	2.05	0.126
7	Goa	0.88	0.003
8	Gujarat	35.77	2.440
9	Haryana	4.56	0.224
10	Himachal Pradesh	33.84	0.022
11	Jammu & Kashmir	111.05	0.014
12	Jharkhand	18.18	0.034
13	Karnataka	24.7	6.096
14	Kerala	6.11	0.138
15	Madhya Pradesh	61.66	1.840
16	Maharashtra	64.32	1.634
17	Manipur	10.63	0.003
18	Meghalaya	5.86	0.001
19	Mizoram	9.09	0.005
20	Nagaland	7.27	0.001
21	Odisha	25.78	0.395
22	Punjab	2.81	0.906
23	Rajasthan	142.31	3.227
24	Sikkim	4.94	0.000
25	Tamil Nadu	17.67	2.575
26	Telangana	20.41	3.592
27	Tripura	2.08	0.005
28	Uttar Pradesh	22.83	0.960
29	Uttarakhand	16.8	0.306
30	West Bengal	6.26	0.075
31	UT	0.79	0.070
	Total (GW)	**748.97**	**28.181**

Solar energy is mainly dominated in Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh. Fig. 5 illustrates the average annual solar radiation potential capacity in India [55]. Rajasthan and Gujarat region in India has been the highest potential of radiation around 2150 kWh/m^2. Rajasthan is the highest developed state in terms of solar power because its estimated solar potential is 142.31 GW and as on 31.03.2019, the total solar installed capacity is 3.227 GW. Also, a 4 GW solar project is being started in this state.

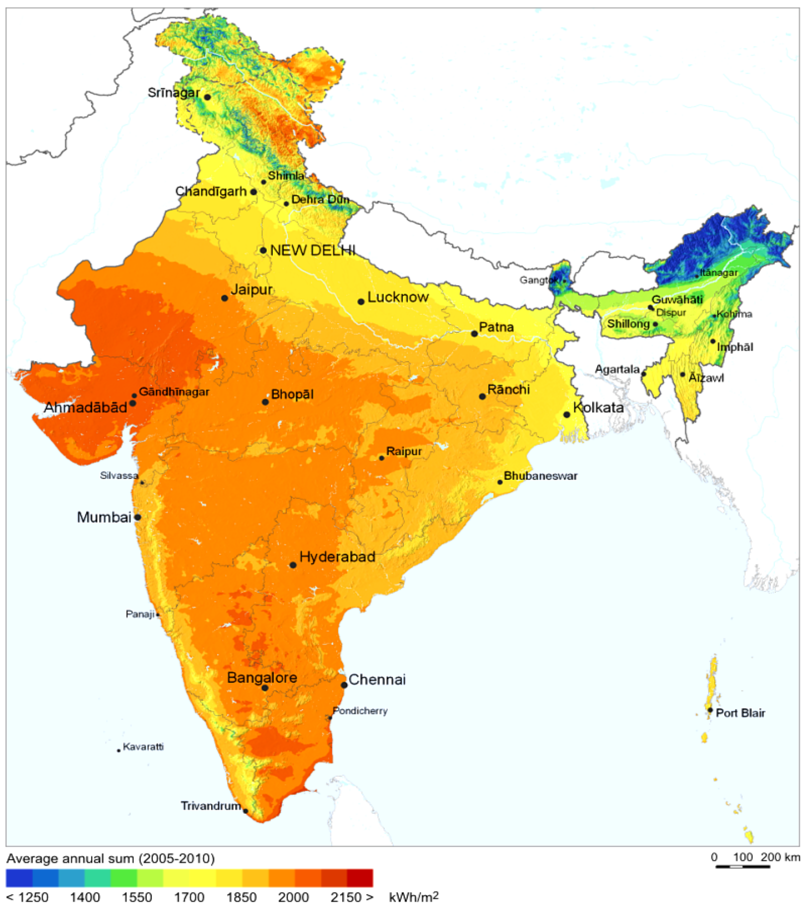

Fig. 5. Illustrates average annual solar irrradiation (kWh/m^2) potential in India (*Source* [55], p.13) .

In northern India, lowest solar potential states are Jammu and Kashmir and Himachal Pradesh. The western part of India has emerged as a solar power leader due to various features such the high potential of solar power, easily availability of wasteland, strong transmission and distribution network, good connectivity, and efficient utilities. At present, installed capacity of solar power in Gujarat state is 2.44 GW while the solar potential is 35.77 GW there is huge potential to tap solar power in this state. Maharashtra, MP and southern region of India have the second highest region for radiation with 2000 kWh/m^2. A 750 MW solar power project was proposed by MP state. Also, a large utility solar power project of 648 MW in Kamuthi of Tamil Nadu state was formally committed to the nation. Eastern region of India shows the lowest solar radiation pattern with less than 1550 kWh/m^2. The lowest installed capacity of solar power is 0.01 MW in Sikkim due to the low solar intensity pattern.

5 Discussions

The highest value of GHI is 6 kWh/m^2/day and DHI is 3.8 kWh/m^2/day with corresponding ambient temperature is 30.1 ^{o}C in the month of June 2015 and found a good relationship between these parameters. In the month of December 2015, the lowest average value of GHI is observed with the corresponding ambient temperature of 14.85 ^{o}C. The association of high average value of GHI and DHI with a high average value of ambient temperature is also observed by the Abbas et al., (2017) in his study [47]. The DNI is used for CPV and CSP power plants because this parameter is helpful for the design of the solar plant and work over a longer duration of time. The annual cycle of these parameters varies due to variation of seasons in India. From February to June, this area receives a good amount of solar resources and the low value of relative humidity is observed, which shows a good relationship among these parameters. Moreover, relative humidity is the factor that has a great impact on the solar radiations. It is also observed that when ambient temperature decreases the relative humidity increases as found in the month of January and October to December. Abbas et al., 2017 [47]; Ettah et al., 2015 [48] analyzed the effect of relative humidity on solar plant generation and found that when relative humidity decreases, the current output as well as the efficiency of solar power generation system increases. Therefore a good correlation is observed among DNI and relative humidity.

In India there is plenty of wastelands is available and it is sufficient to generate clean and green power which can fulfill the entire demand of the nation. Moreover, the estimated potential of solar power is 748.98 GW when considering the 3 % wasteland of the country. It is also evaluated that there is a huge difference among potential estimation and solar installed capacity. So there is ample opportunity to harness solar power in India.

In conclusion, this study shows the effect of variation of solar radiation resources and variation of meteorological parameters in the area of Murthal, SRRA station. The GHI radiation parameter is explored to study the impact of solar irradiance on solar photovoltaic as well as on the solar thermal system. GHI is evaluated using the sum of DNI and DHI with respect to the incident radiation. These meteorological parameters also have an effect on solar irradiance, which further affects the output performance of the solar power generation system. In addition to these solar resources of the country also helps to assess the solar potential, performance, and selection of futuristic solar technologies.

6 Conclusions

Availability of clean, reliable and sustainable energy plays a critical role for industrial as well as the socio-economic development of any country. It is essential to assess solar radiation resources and solar potential for harnessing solar energy in India. Solar and meteorological data plays a critical role for accurate estimation of solar potential, solar technology selection, research and development in the field of solar, policymakers and project developers. The conclusions of this study are as follows:

- There are 121 solar resource stations were commissioned in India with a central receiving station at NIWE-Chennai, which is responsible to disseminate solar data for the development of solar power in India.
- This study analyzed the one-year solar radiation data from January 2015 to December 2015 of DCRUST, Murthal station. The maximum monthly average GHI is 6.0 $kWh/m^2/day$ in the month of June, while the corresponding ambient temperature is 30.1 ^oC. The minimum monthly average GHI is 2.1 $kWh/m^2/day$ in the month of December and the corresponding ambient temperature is 14.8 ^oC.
- A good relation was found among GHI and ambient temperature. This area received a good amount of solar irradiance from February to October. Moreover, the association of high GHI with the high value of ambient temperature behavior is also observed by other authors in a different part of the country.
- The relative humidity is observed at the higher side when the ambient temperature is at the lower side as seen in the month of January and October to December. In addition to this relative humidity decreases the DNI part of solar irradiance. Due to this a good relationship is observed among relative humidity and DNI.
- The maximum landmass of India received greater than 1700 kWh/m^2 average annual solar radiation and this offers hugee potential to harness solar power.
- In India, the estimated solar potential is 748.97 GW, while the total solar installed capacity as on 31.03.2019 is 28.181GW. Due to the huge difference between estimated solar potential and solar installed capacity, there is great opportunity to harness the solar energy and fulfill the entire electricity demand of the nation.

The utilization of advanced instruments for solar resource estimation in India helps to develop new solar power projects and advance technology. This analysis of solar resources will support to develop solar maps, evaluate the feasibility of solar projects and will act as a base for the development of futuristic solar technologies. Moreover, this study helps to deploy solar energy not only in India but also in neighboring countries.

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