Understanding the impact of clouds and atmospheric aerosols on solar energy generation in India and Finland.

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Abstract

India-being a solar resource opulent country with a strong policy commitment from the Central government has attained extraordinary developments in solar energy installations. India as a leader in renewable energy has total grid connected capacity of 43.7 GW RE installations, out of which around 62% share from wind and 17 % from solar PV. With a progressive target of 100 GW of solar energy installations by the year 2022, India is taking a big leap in meeting its own power demands from solar PV. In future, the role of solar PV will be substantial to reduce dependency on imported and depleting conventional fuels. Seeing the importance of solar power, it becomes essential to analyze and forecast the information allied to solar radiation coming from sun. Further, India is positioned under such a climatic zone, where presence of atmospheric aerosols strongly influence solar resource availability, therefore development of robust forecasting methodologies for predicting solar resource availability becomes essential for grid management. In Finland, solar radiation is marginally affected by aerosols presence but it has largely influenced the presence of short time varying clouds. Influence of clouds and atmospheric aerosols on solar energy in India and Finland (ICASIF) is a joint project between the two countries; funded by the Department of Science and Technology (DST), Government of India, and the Academy of Finland which is being implemented by The Energy and Resources Institute (TERI), India and Finnish Meteorological Institute (FMI). The study investigates the above said issues with an overall aim of providing information on the impact of clouds and aerosols on solar radiation and impact of these factors on electricity production.

Keywords- Aerosols; Solar radiation; Cloud; Forecasting.

INTRODUCTION

The alarming level of pollution in Indian cities has pushed county's climate security on the back foot. Increasing number of hazardous atmospheric particulate and poor air quality constraints has created issues of health hazard and significant drop in solar power. A recent study on impact of atmospheric aerosols and power generation indicated ~17-25% reduction in solar power generation [1] due to atmospheric particulates. Hence, it becomes essential to evaluate the perfect forecasting methods in order to examine the effects and subsequent actions to minimize the cause.

India and Finland both countries fall in separate climatic zone. In India, solar energy sector is majorly affected by the aerosols presence in the atmosphere [1,2] and unlike India, Finland is a Nordic country which has a yearly average solar potential of around 900 kWh/m^2 [3] and mostly the radiation controlled by the clouds. In this context study of clouds and aerosols becomes significant for India and Finland respectively.

METHODOLOGY

The whole study was categorized into six work packages and each work packages reflects the correlated activities proposed:

1) Measurement and analysis of aerosols and solar radiation.
2) Improvement of satellite estimates of solar radiation over India.
3) Forecasting of solar radiation on the basis of satellite observed clouds.
4) By using the forecasted aerosols information forecasting of solar radiation.
5) Understanding the effect of variations in the solar spectrum on solar PV energy output.
6) Future availability of solar radiation.

For the analyses of the data, two locations in India and Finland each were finalized. Locations were selected on the basis of low and high aerosols presence.

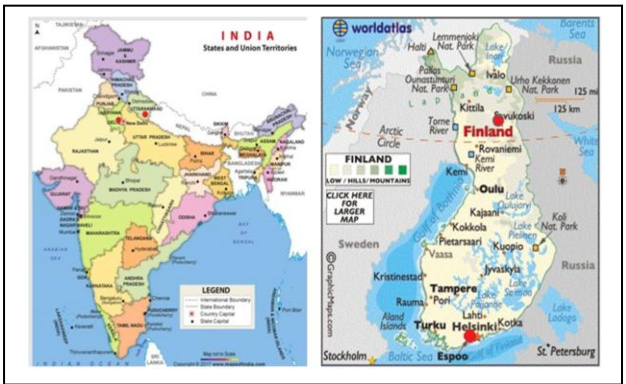

Figure 1: ICASIF stations in India and Finland [4, 5]

Figure 1 shows the stations established: Mukteshwar, Gwalpahri (India) and Pallas, Helsinki (Finland).

In India Himalayan region (Mukteshwar) have low aerosol load [6]) and Indo-Gangetic plain (Gwalpahari, Haryana) is found to be highly polluted [7]. Similarly the stations finalized in Finland were Pallas and Helsinki, respectively.

INSTRUMENTS DEPLOYED FOR MEASUREMENTS

Under ICASIF project various aerosol and clouds measuring instruments (Table 1) have been deployed in selected places in both the countries. Currently, measurement activities at Mukteshwar & Gwal Pahari campuses of TERI, India and Helsinki & Pallas in Finland are under way.

TABLE 1: INSTRUMENTS AND IT'S WORKING UNDER ICASIF

S.N	Details of ICASIF Instruments		
	Name	***Manufacturers***	***Usages***
1	Flame Spectrometer	Ocean Optics	Solar spectrum (350-1000 nm)
2	Opticle Particle Sizer (OPS)	TSI	Particle size distribution in atmosphere
3	Sun-Photometer	CIMEL	Aerosol optical thickness at particular wavelength
4	Ceilometer (CL-51)	Vaisala	Aerosols and cloud base height
5	Diffrenal Mobility Particle Sizer	TSI	Particle concentration, particle size distribution in the atmosphere.
6	Aethalometer	Magnee Scientific	Mass concentration of black carbon.
7	CAPS PMex	Aerodyne research	Optical Extinction of solar radiation due to aerosols.

The above instruments are collecting relevant data on 24 hours basis and favorable conditions are being maintained to run the system efficiently.

Figure 2: TERI-FMI Labs in India, Left –Mukteswar and right - Gwalpahari .

Figure 3: TERI-FMI Lab in Finland

In above figures 2,3, instruments to measure solar spectrum and aerosol parameters such as size distribution, aerosol optical thickness (AOT), backscatter profile and black carbon concentrations are being used. The measurement activities at all these locations are being carried out for more than a year and will be continued for next couple of years, which will lead to a continuous, valuable solar spectrum, aerosol data base and will be used for future research. Also teams from implementing agencies have been involved in validation of ground data with satellite data. The aim of this exercise is to improve satellite estimates of solar radiation over India.

MEASUREMENT AND ANALYSIS

The instruments which are continuously collecting datasets on aerosol and other required parameters and its effect on solar radiation analysis are under process.

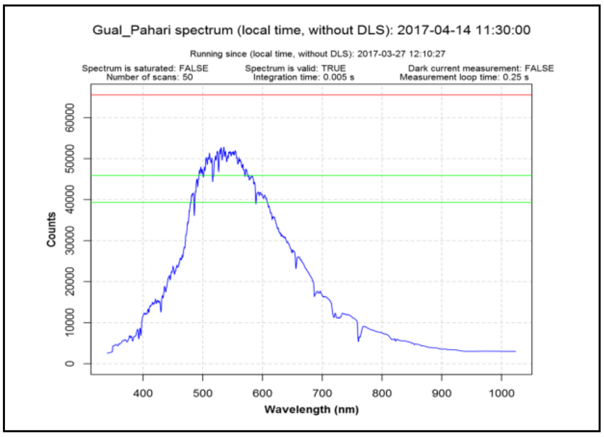

Figure 4: Solar spectrum at Gwalpahri station on April 2017

The figure 4 revealed the spectrum of the solar at particular time on April 2017, which was recorded by the flame spectrometer for a specified wavelength 400-1000 nm.

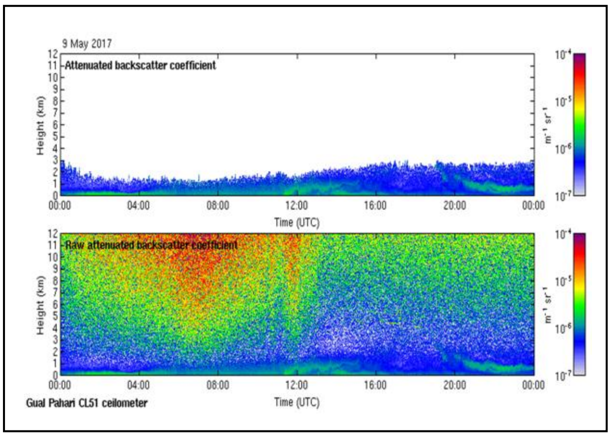

Figure 5: Attenuated backscatter co-efficient recorded by Ceilometer for Gualpahari

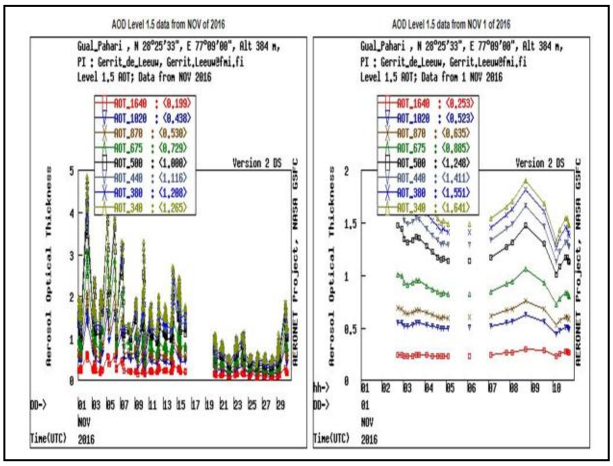

Figure.6: Aerosol optical depth measured by Sun-photometer.

Figures 5, 6 depict data collected by the Ceilometer and Sun photometer (CEMEL). Fig 5 is showing the backscatter co-efficient for a typical day in November 2016. Raw Attenuated backscatter co-efficient was filtered till 3 Km height and thus resulted attenuated backscatter co-efficient drawn.

Aerosol optical depth (AOD) of November 2017 has been depicted in fig. 6, which shows higher aerosol load over the study region.

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