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Solar Power Technologies-Feasibility Assessment: Northern parts in Kerala.

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Abstract— Solar power is perhaps another Holy Grail in the making for researchers and easily the object of an extended quest. After slowly taking foot hold in the world energy market, solar has almost single handedly taken the energy landscape by storm. To build upon and make the best use of appropriate technologies that will boost the proper utilization of solar energy harvested from different fields presupposes a receptive and competitive ambience. As of now, Solar occupies the centre stage in among the mature renewable technologies, and thanks to this fact the impact of solar in the nook and corner of energy market is as spectacular as it is visible. This paper focuses on a detailed feasibility study of solar radiation resource assessment covering the northern part of Kerala, based on data collected from places as different and diverse as Calicut, pookode, Edakkal, kasaragode, and wayanadu. The objectives of the assessment were: to assess the possibility of implementation of solar energy conversion techniques, to evaluate the challenges of resource limitation and associated economic disadvantages and to assess the efficiency to help design an optimized system with low build cost and specialized materials. The analysis has been carried out based on daily solar irradiance and clearness index obtained from various Meteorological department sources. An overview of four solar power technologies (Parabolic trough collector, Heliostat Field Central Receiver System, Parabolic Dish Collector Technology, & Computed Linear Fresnel Reflector) is given in this study. As a first step, solar irradiance variation and other climatic parameters over various locations have been recorded. So also, the monthly data. The transition of day light hours and seasonal changes were noted. A brief discussion of the primary mechanism of all the four Solar power technologies for concentrating sunlight, comes under the remit of this paper. The proposed technology suitable for the specific part of the state / location is also discussed. The site specific finding shows that CSP application is a promising solution for the problems besetting the energy landscape.
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Index Terms— Clearness Index. Global Solar Radiation, Singularity exponents, Multi-scaling, Power Generation, Solar Concentra tion, Wavelet Transform Modulus Maxima.

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1 INTRODUCTION

There is no single subject as ‘Energy’ which has engaged the continued attention of the world at large about which it is still listening to in rapt attention. Researchers and laymen alike are rhapsodizing about the high potential of the solar energy resource and its ability to cater to the increasing needs of the world, so much so that raging efforts are on the rise to ratchet up the use of solar as never before.

The raison d’etre for concentration of so much of research activity on solar is the overall acceptability of solar against other energy resources as being the most clean At the same time there is there is literally no end in sight to the endless debates about whether to go in for drilling more oil or mining more coal or falling back squarely on sustainable clean energy resources such as wind and solar which are termed as clean renewable, for the simple reason they lend themselves to be replenished over and over again unlike fossil fuels, which only create smoke stacks with the attendant disadvantages like profuse GHG emissions and highly toxic particulate matter and other suspended particles. At any rate the renewed interest in solar energy is whetting the appetites of a energy hungry world. As is well known, solar radiation concentrates on the spectrum ranging between 200 to 4000 nm and solar energy can be converted directly or indirectly into other forms of energy such as heat and electricity. The downward solar radiation at the top of the atmosphere is about 1367 W/ m^2 with associated uncertainty of 1%. The total annual downward solar energy at the surface is about 3.3* 10^{24}J, which is roughly 6800 times more than the world annual energy consumption. In many regions of the world, one square kilometer of land (0.5% of land surface) is enough to generate as much as 100-120 GWh of electricity (equivalent to 50 MW conventional coal/gas fired plants energy generation), per year using solar thermal technology. Isaac Berzin’s method of producing algae fuel is a revolutionary concept which seeks to take advantage of the fact that algae produce 30 times as much oil per acre as sunflowers do and most important they thrive in sewage or brackish water and devour carbon dioxide. The United States Department of Energy has estimated that if algae fuel replaced all the petroleum fuel in the United States, it would require 15,000 square miles (39,000 km^2) which is only 0.42% of the U.S [9].Further, PV energy is produced from the conversion of sunlight into electricity through a solar cell, a non mechanical device usually made from silicon alloys. Solar thermal power is a relatively new technology which has already shown enormous promise. It

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is essentially the same as conventional technologies except that it uses the thermal energy from solar heating rather than stored energy in fossil fuels released by combustion. With little or no environmental impacts and a massive resource, it offers a goldmine of untapped resources and opportunities in the sunniest regions of the earth located between 40′ N and 40′S. Solar thermal technologies use concentrator systems due to the high temperature needed for the working gas or fluid. Advanced technologies, mass production, economies of scale and improved operation will together enable a reduction in the cost of solar electricity to level which compares favorably with peak oil and mid load power stations with in one or two decades.

In this helio-centric world of ours, India is geographically located in the sunny belt of the world and it receives abundant radiant energy of the order of about 6000 Million GWh per year.[1].The daily average global radiation is around 5KWh/m^2 in north eastern and hilly areas to about 7KWh/m^2 in western regions and cold desert areas with the sunshine hours ranging between 2300-3200 per year. In most parts of India, sunny weather ranges from 250 to 300 days a year with solar radiation of 4.6 to 6.4 KWh/ m^2 /day. Though India is blessed with good sun shine, it is far lagging behind countries like Germany, France, Spain, Netherlands, Israel, Austria, US and now China. Since , solar energy is renewable, modular, long lasting and even reliable to a great extent in the Indian context , unlike in other countries , entailing little maintenance costs , and no running cost at all by way of fuels costs, there is a strong case for going for it. However, detailed study and investigation of the solar radiation and the variability must precede any exercise at implementing solar , as this component is influenced by many factors as varied as site location, latitude, longitude above MSL, clearness index, direct normal radiation, seasonal variation etc. Details of such components can be acquired by installing high resolution real time meteorological instrumentation devices to collect and record variations in different weather components as, it is extremely important that an informed choice is made.[2-3].Therefore, accurate and detailed long term knowledge of the available solar radiation is of importance for the design and development of solar energy conversion systems. Kerala is endowed with conducive meteorological and topological setting. Excepting for some patches of the experimental units, no major attempt has been made in the state in the direction of solar power generation. The quantum of grid connected solar system in Kerala is at present only 0.175 MW, whereas that of India is 47 MW [4]. However, the capital cost required for installing a solar power generating station is 30 times more than that of the conventional one . The current status of solar is that even as technical advancements are being achieved in the field of tapping of solar energy, still the number of grid connected solar generators is yet to take off to the desired goal. Among the mature renewable technologies, CSP is the most adaptation–compliant one, that can be built in a range of sizes from few MW up to several hundred MW with the additional advantage over PV like consistent output thermal storage capability, in that it can stand variation of sunlight owing to overcast sky as well as generation of power during night hours. What is more, it can be configured with varying levels of storage to suit local weather condition in tune with the requirements of local grid operator. Over and above this, the optional heat storage implies that power generation can be pressed into service even when the sun is not shining .

In section II an overview of four solar power technologies (Parabolic trough collector, Heliostat Field Central Receiver System, Parabolic Dish Collector Technology, & Computed Linear Fresnel Reflector) are given. Section III on the other hand, provides an account of location and data study based on singularity point (WTMM Method) approach. In section IV, our results are summarized and finally section VI gives the concluding remarks.

2 SOLAR THERMAL POWER CONVERSION TECHNOLOGIES

Producing electricity from sun shine is essentially a straight forward technology in that it can be concentrated and collected by a range of CSP technologies to provide medium to high temperature heat. The four most promising solar thermal technologies, using CSP's are the parabolic dish collector, parabolic Trough collector, Linear Fresnel Reflector & Heliostat Field Collector. CSP plants produce electricity by converting the IR part of solar radiation into high temperature (used for power generation, process heating & desalination purposes etc.,) using various mirror/reflector and receiver configurations.

2.1 Parabolic Dish Collector (PDC).

In PDC, a heat engine is mounted on one of the focal point of a parabola dish to collect heat energy from solar irradiation . The concentrated solar flux onto the heat engine produces mechanical work which is then directly converted into electricity. The application characteristic of PDC generally include stand alone, small off grid power systems to clustered larger dish connected parks with the advantage of modularity and mass production .

2.2 Parabolic trough Collector (PTC).

PTC's are by themselves , long arrays of parabolic trough shaped mirrors used to concentrate sun light onto thermally efficient receiver tubes placed in the trough's focal plane. A heat transfer fluid made to circulate in these receiver tubes, after getting heated by sun rays to the order of about 400^0C is then pumped through a chain of heat exchangers to produce super heated steam, which is converted into electrical energy by steam turbines. The predominant systems in vogue in the world are PTC's with the advantage of high operating temperature potential with low operating cost and hybrid concept.

2.3 Linear Fresnel Reflector (LFR).

In principle, LFR and PTR''s are quite similar except the fact that LFR uses long, flat or slightly curved mirrors that reflect light onto a linear receiver mounted 5-19m above ground. They can be used in grid connected plants or steam generation in thermal power plants as they use flat reflectors with low manufacturing costs [5-6].2

2.4 Heliostat Field Collectors (HFC).

HFC collect solar energy by massive arrays of large flat mirrors that focus light onto the top of a tower of height 35-60 meters where a large receiver containing heat transfer fluid is mounted. The operating temperature potential of HFC is beyond 1000^0C and is better suited for dry cooling concepts applied in grid connected plants with high process requirement. Moreover, HFC can be used to provide base load with dispatchable power [7].

The CSP plants, faces challenges due to the difficulty of sitting them without disturbing environmentally or culturally sensitive lands and the competition from PV plants. Despite challenges, CSP holds advantage over PV technology in that it experiences fewer intermittency issues coupled with potential to use integrated storage to align its output with peak demand periods.

3 DATA AND LOCATION ANALYSIS.

The annual global radiation varies from 1600 to 2200 KWh/ m^2, which is comparable with radiation received in the tropical and sub tropical regions. Although the highest annual global radiation is received in Rajasthan, Gujarat (Northern region), Tamilnadu, Andhra Pradesh ,Maharashtra and Madhya Pradesh , Karnataka and parts of Ladakh also receive fairly large amount of solar radiation as compared to many parts of the world. These points to the option of a viable solar power project.

In Kerala, the uptake of solar thermal electricity has so far been limited to demonstrations, though solar thermal concentrators are currently used in at least two locations to provide heat for water heating and cooking. The Northern part of Kerala is best suited for solar based studies because the location receives maximum amount of solar radiation annually. Solar irradiation data of Calicut, pookode, Edakkal, kasaragode, and wayanadu are listed in Table 1, which clearly shows that northern parts of the state receive good amount of annual average solar irradiation. The geographical data of the test sites are listed in Table.2.. Hence before any capital investment can be made, precise knowledge of solar radiation incident over the earth's surface must be obtained taking into account the design and development aspects of solar conversion technology. Apart from this, resource assessment is to be done with utmost priority for the success of a solar power plant. The solar irradiation data and other climatic parameters across different sites measured by Indian Meteorological Department are taken. Every ten minutes, the mean values of the solar irradiation data recorded are taken. The collected data from different sources were converted into time series signals and the average monthly global irradiation for the test sites is analyzed from the singularity point approach using WTMM Method to find the different scaling factors associated with each site. We used the time series data from 2010 and 2011 and in each year a series of 105, 408 data points, and in the monthly analysis a minimum of 41,76 values .

TABLE 1

IRRADIATION FIGURE IN DIFFERENT CITIES IN KERALA IN KWH/ M^2/ DAY(2010).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Kasarkod	**6.06**	**6.06**	**6.18**	**5.55**	**3.70**	**3.70**	**3.98**	**3.98**	**5.88**	**.88**	**4.89**	**5.42**
Calicut	**6.87**	**6.86**	**6.99**	**6.51**	**5.81**	**4.16**	**4.22**	**4.22**	**4.81**	**5.51**	**5.22**	**5.49**
Edakkal	**6.45**	**6.44**	**6.45**	**5.74**	**5.31**	**5.31**	**3.84**	**3.84**	**3.66**	**4.00**	**4.78**	**4.64**
Wayanadu	**6.25**	**6.25**	**6.45**	**5.74**	**5.31**	**5.31**	**3.84**	**3.84**	**3.66**	**4.00**	**4.78**	**4.64**
Pookode	**6.60**	**6.60**	**6.45**	**5.74**	**5.31**	**3.84**	**3.66**	**4.00**	**4.78**	**4.64**	**4.94**	**5.46**

TABLE 2.

GEOGRAPHICAL LOCATIONS OF TEST

Site	**Latitude**	**Longitude**
Edakkal	**11.6257966**	**76.2356005**
Pookode	**11.5440664**	**76.0246845**
Wayanadu	**12.4386702**	**75.2012290**
kasargod	**11.5440664**	**75.2012290**

4. WTMM METHOD .

Mallat has proved that all singularities of irregular signal (multi fractal signal) could be detected using WTMM in partition function. Numeric analysis performed in our work

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was based on WTMM method .This is one of the commonly used approaches to study multi scale structures in complex time series. Using WTMM in partition function, we can avoid the deviations that are made by the oscillation of wavelet coefficients when q< 0.That is, WTMM is associated with the possibility of analyzing a wide range of scales from small fluctuations and weak singularities to large fluctuations and strong singularities. In this approach, the numerical quantification of time series is done by the so called singularity spectrum D(h) characterized by the holder exponent h. in this work solar irradiation is studied in terms of the percentage of frequency distributed at different times. Thus one value may be taken as the irradiance fraction s in a certain time t. Thus s can be defined as the probability of finding velocities of a certain value within the interval i.

For a continuous process with spectral density $\acute{\Gamma}_x(v)$, we define the wavelet transform coefficient as:

$$T_\Psi|f(x_0,a)| = \frac{1}{a}\int_{-\infty}^{\infty} f(x)\,\Psi\left(\frac{x-x0}{a}\right)dx \qquad (1)$$

Where $f(x_0)$ is a distribution at a point x_0, a is the sale parameter, and Ψ is the wavelet. A local singular behavior of f(x) at the point x_0 results in an increase of $|T_\Psi|f(x,a)||$ as $x \to x_0$. And can be characterized by the Holder exponent $h(x_0)$ that quantifies the scaling of the wavelet coefficients for small a The structure of the probability measure on the segment $[t_i, t_j]$ may be defined by the scaling relation

$$T_\Psi|f(x_0,a)| \sim \alpha^{T(q)} \qquad (2)$$

The Further, the statistical description of local singularities is performed using the notion of the partition function S(q,a) [8] being the sum odd the q^{th} powers of the local maxima of $|T_\Psi|f(x,a)||$ at a scale α (i.e., is the length of the sub intervals in which total segment is divided). For small α, the partition function S(q,a) scales as [8]:

$$S(q,a) \sim \alpha^{T(q)}, \qquad (3)$$

with the scaling exponent $\tau(q)$.The partition function is spread over the interval in such a way that concentration of solar irradiation velocity varies widely and a different behavior is expected at different spatial positions i. Many sites i may share the same exponents when a regular covering of a particular size is chosen.

The singularity spectrum D(h) can be estimated using the Legendre transform :

$$D(h)=q(h)-\tau(q) \qquad (4)$$

With

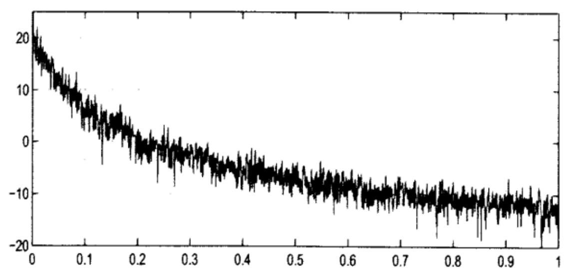
$$h(q)=d\,\tau(q)/dq \qquad (5)$$

The singularity spectrum describes the statistical distribution of the singularity exponent h(q) or it counts the how often specific values of h (q) of the singularity may occur.

For positive values of q the partition function S(q,a) characterize the scaling of large fluctuations in the data(strong singularities).For negative q it reflects the weak singularities. Applications of The WTMM method, to time series implies the presence of anti correlated behavior, with h > 0.5 reflecting correlated dynamics .

5. RESULTS AND DISCUSSIONS

Global radiation on horizontal surfaces for five different sites in the northern part of Kerala was collected from well established sites of MNRE etc. Highest average global radiation is 5.66 KWh/ m^2 at calicut and lowest in Edakkal caves with 5.08 KWh/ m^2.The determination of the singularity spectrum of global irradiation h(q) was done for each month separately and also for each year for each site. In Fig.1, the results for 2010 for Calicut are shown. The convex function h(q) varies between months pointing out the different richness of the studied structure. One way to see the variation in complexity between months is to plot the amplitude ($q_{min} - q_{max}$) reached by the spectrum in each one. The months that show a lowest complexity are February, January, July and April 2010.The spectrum for the whole year 2010 is contained in the range of the month's spectrums.



Fig,1 Time Series data for solar irradiation at Calicut.

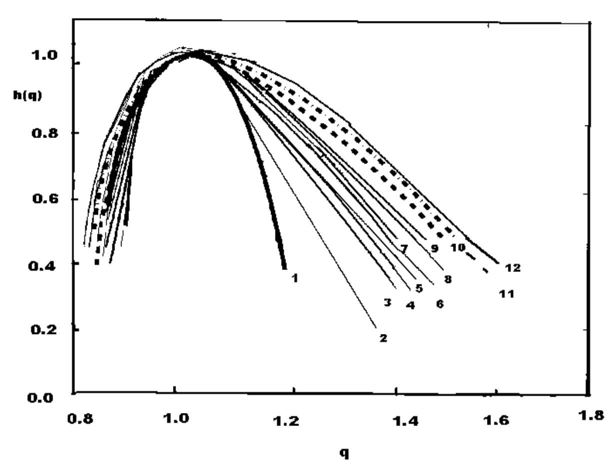


Fig.2.Singularity spectrum for each month and of the whole

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year 2010.

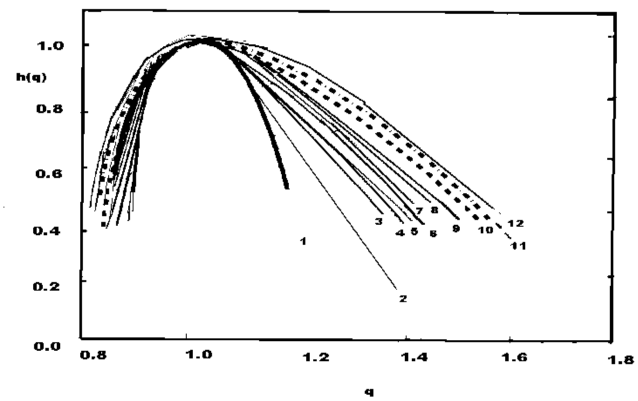

Fig.3.Singularity spectrum for each month and of the whole year 2011.

q

The same results are obtained for the year 2011.However, the months that show higher complexities are different (Fig.3).In 2011, it is June that shows the narrowest spectrum. It is also observed that this month presents a higher frequency of null values as it is reflected by the fact that for q = 0 the h(q) value is 0.9.The overall structure of these time series for each year is almost the same(Fig. 4). The maximum and minimum and average clearness index per month for all locations were calculated and they resemble each other with January enduring lowest clearness index while May shows the highest index .The changes in amplitude of the h(q) singularity spectrum are statistically non significant. However, the scaling behavior at the right side of the spectrum for negative q values can be differentiating. In all the singularity spectrum showed the differences were found always in the range of negative q values, but in the positive q values they are very closed pointing out a very similar scaling.

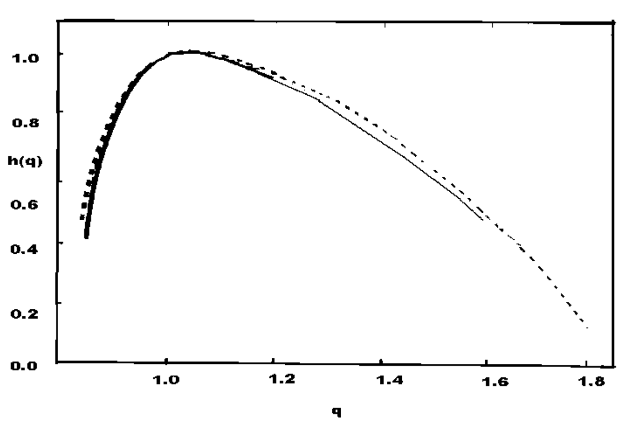

Fig.4. Singularity spectrum for each year taking all data series.

Out of all four solar conversion technologies, PDC fares highest weightage to the ideal conversion efficiency and collector efficiency with greater operational efficiency. As for the northern part of Kerala, water availability is not a major worry compared to land requirement. In all the five sites land requirement is the major concern and Edakkal caves is the best option to start solar based thermal power plant. Taking into account all advantages and limitations of all CSP'S it is suggested that LSR is suitable choice for Kerala due to less land requirement, low cost and hybrid possibility.

6. CONCLUSION

High resolution measurements of global radiation for five different locations in the northern Kerala were analyzed for the year 2010-2011 and were used to study the possibility of implementing solar energy conversion (CSP) technologies. The result shows that CSP application in northern Kerala is a promising solution to energy expansion in the country along with other alternative resources. Though the studied sites have well enough solar potential, concentrating solar power is met with challenges as varied as resource limitation, economic disadvantage, build costs and operational costs which are being improved through optimized system design and better specialization of materials. In terms of modeling irradiation time series, and the process they reflect, characterization of multi scale heterogeneity is to be done. Based on the modeling characterization, realistic simulation can be done with

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